COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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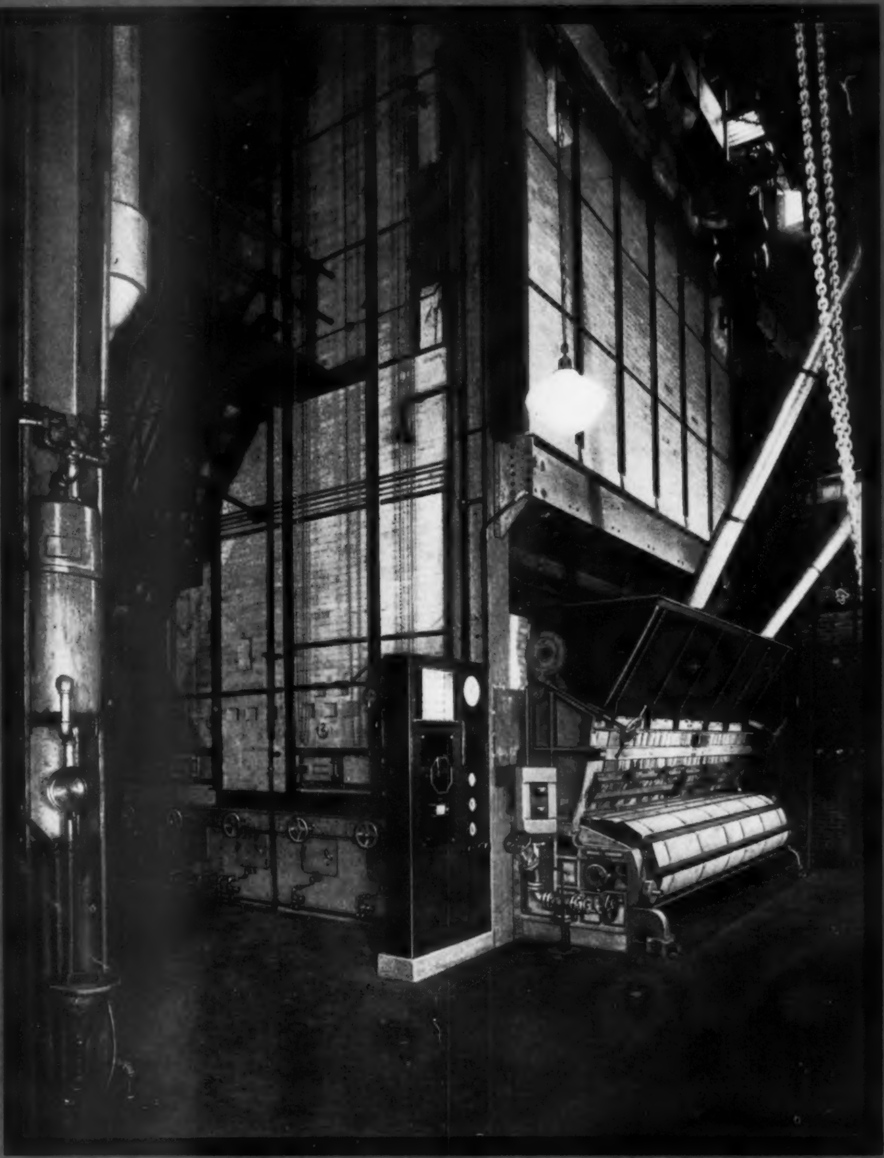

New Boiler Unit at Plant of Colgate-Palmolive-Peet Company, Jersey City, New Jersey

District Steam Heating—I

Spontaneous Combustion in Coal Storage Piles

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SEVEN | NUMBER THREE

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FOR SEPTEMBER 1935

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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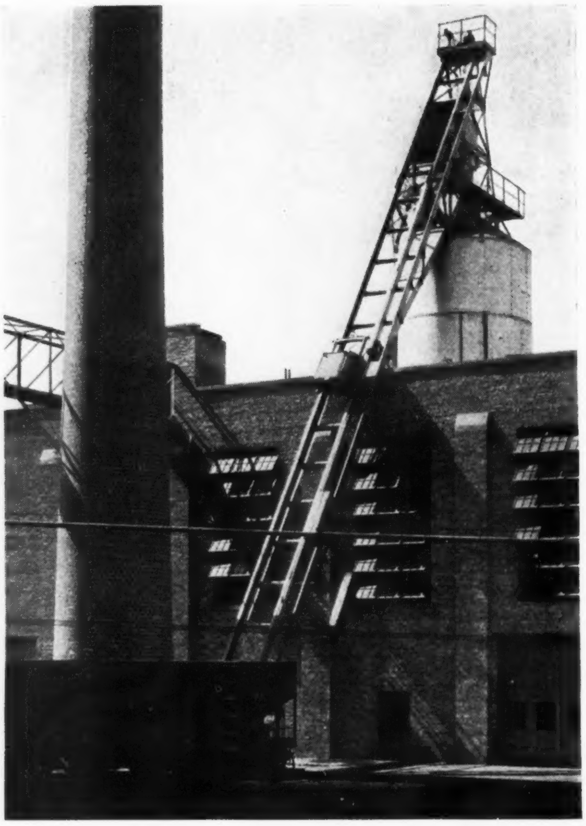

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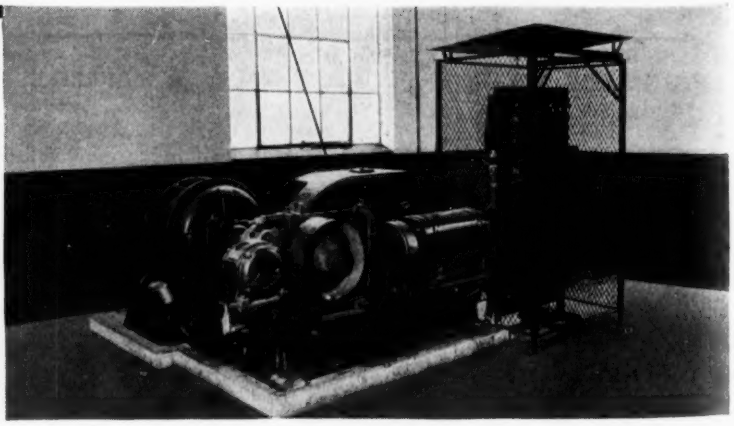

EDITORIAL

A "Close Up" of the District Heating Situation

In this issue appears the first of a series of three articles by Roger D. DeWolf on district steam heating. That this industry has long been regarded as a "step-child" by many of the electric utilities is apparent. Just why it has been so regarded is frankly told by the author whose intimate association for many years with both industries enables him to express opinions based on first-hand information. Despite early pitfalls, involving heavy losses, district heating has grown and in many cases losses have been changed into substantial profits. Changing economic conditions, the public's response to service and technological advances in steam generation, distribution and utilization now combine to offer a promising future for district steam supply for both domestic and industrial use.

We read much these days about what the Federal Government is doing in its attempt to extend rural electrification and to further the use of electricity in the home. It is equally logical that it endeavor to spread the convenience of district heating among domestic consumers.

In the succeeding articles Mr. DeWolf will show how full economic advantage can be taken of steam generation and distribution at higher pressures and temperatures, with accompanying higher velocities, smaller piping, lower radiation losses and reduced capital expenditure. The combination of power generation and steam supply with small or medium size turbines, under automatic control and located at load centers or on the customers premises, are shown to offer promising possibilities. The industrial supply of steam, as well as steam for heating will be discussed, as will be rates, fixed charges and the potential growth in load.

In view of the importance and timeliness of the subject and the author's standing and acquaintance in the field it is anticipated that the articles will be widely read. At the conclusion of the series, discussions will be welcomed.

Standardizing Symbols

Many of the larger drafting rooms have their own standard practices that have been developed over a period of years to suit their particular requirements. These involve a large variety of symbols, some of which have sound basis for existence while others have been adopted as expedients in the absence of something better. While adequately serving the purpose of individual manufacture, it has been found that these symbols often lead to confusion when a drawing is supplied to a manufacturer of equipment that must function in conjunction with the first equipment. In an attempt to obviate this situation a graphical dictionary of symbols has been compiled by representatives of thirty national organizations and a number of independent experts and the work has been adopted by the American Standards Association.

In any field it is difficult to introduce new standards to replace practices of long standing. Not only is there a natural inertia resisting change but the changes, while admittedly desirable, may be difficult to put into effect because of industry preferences as well as individual desire. Hence the adoption of new standards is usually a slow process. Nevertheless, the American Standards Association has accomplished much toward the elimination of waste, the adoption of acceptable practices, the avoidance of confusion and the use of a common language in engineering terms. This latest effort is in the right direction. Few firms will probably find that it completely covers their requirements and fewer still will find it convenient immediately to adopt it entirely. Nevertheless its partial adoption will serve to eliminate much of the present confusion concerning symbols on engineering drawings.

Observations

Following the return of Chairman McNinch of the Federal Power Commission from a meeting in London of the Executive Committee of the World Power Conference, President Roosevelt requested Congress for an appropriation of $75,000 to defray the expenses of a World Power Conference in this country next year. If such a meeting is held the program is likely to be quite different from those of former Conferences in which the programs sponsored by the then existing American Committee was marked by the absence of papers dealing with public ownership. What a difference a few years will bring about.

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Now that the much discussed and bitterly fought utility legislation has been passed, there is likely to be long drawn out court action to test its constitutionality and then perhaps a re-arrangement of holding company structures within state lines to include integrated properties. Meanwhile the load continues to grow, with a seasonal output already five per cent above that of 1929, and further growth must be anticipated despite the situation brought about by recent legislation.

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When the Richmond Station in Philadelphia was built in 1925 twelve boilers were required to provide steam for 100,000 kw turbine capacity. In the extension just completed two boilers supply 165,000 kw. One wonders whether the next ten years will show comparable advances in the concentration of power in large units.

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A new use has been found for dry ice. One of the utility companies reports its use for removing turbine diaphragms which could not be removed by the usual procedure.

DISTRICT STEAM HEATING—I

By ROGER D. DeWOLF
Consulting Engineer,
Rochester, N. Y.

This introductory article of the series reviews the history and many pitfalls of the district heating industry when steam was sold largely as an adjunct to building electrical load. Subsequently, where steam was sold as a service rather than a commodity, and at commensurate rates, profits replaced losses. The two succeeding articles will discuss the future possibilities of district steam supply for both heating and industrial use and examine the economics of steam generation and distribution at higher pressures and temperatures, also the generation of by-product electricity by medium size automatically operated turbines located at convenient load centers or on the premises of a large customer. Mr. DeWolf needs no introduction to either the steam heating or the electrical utility fields, in both of which he took a prominent part for many years. He was a former chairman of the Prime Movers Committee, N.E.L.A., has long been active in the National District Heating Association, and while with the Rochester Gas & Electric Company was responsible for much of its work in the steam heating field. He is therefore well qualified to discuss this subject authoritatively—Editor.

IF one agrees with those who claim there is nothing new under the sun, the origin of district heating might be associated with the luxurious Roman suburb of Pompeii. Such an assumption may not be so far fetched as one might casually assume, for the Pompeians had about every other good thing available, and would certainly have appreciated and enjoyed the cleanliness and convenience of such a system.

Passing lightly over a period of some eighteen hundred years, we come to Birdsell Holley, who, in 1877, installed a steam pipe wrapped in swaddling clothes with a boiler at one end and several residences at the other. The inhabitants of said residences having survived the first winter without the inconvenience of having to shovel coal in and ashes out, or wondering whether they forgot to put on the check before going to bed, and going down cellar in the long nightgown of our grandfathers to find out whether the flue would overheat and set fire to the house, it was decided that the idea had some merit and that it would be worth while to make an effort to recover some of the convenience and luxury of the ancient Roman days. So, in Lockport, New York, the infant industry crept slowly through the village streets, bringing warmth, comfort and safety to many a business building as well as residence. From this modest beginning, the American District Steam Company developed.

About this time, another crank appeared with a new kind of light which would light itself without the aid of a match; and slowly thereafter electricity began chasing itself around, turning wheels lighting lamps and being generally useful; and another idea came to the minds developing district heating. The customer wanted heat, light and power, but the greatest of these was heat.

By putting a little more pressure into the steam, using an engine as a reducing valve, and putting in a larger size pipe to carry the exhaust steam to the customer, they were able to give the customer all three of these things; and so the Lockport Light, Heat and Power Company began its long and useful career.

District heating and the electrical industry at Lockport started out as closely bound as Siamese twins, but elsewhere, district heating became the silent partner of the electrical utility—an unwelcome addition to the utility family.

About forty years ago, the electrical utilities, in expanding their activities from the lighting and street railway field into the power field, started their battle with the isolated plant. The competition was severe. The isolated plant in the department store, office building or hotel supplied its owner during the winter with heat, with light and power largely a by-product from the heating steam, and with steam or high pressure water for operating the elevators; during the summer with light and power, hot water, elevator operation, etc. Of these essential services the electrical utility could supply only light and power.

Electric rates were high, and it soon became evident that if the utility could do nothing more than simply shut down the engines and generators in the isolated plant, leaving the customer to carry on the rest of his operations as before, and sell him his electrical requirements for the year from the utility system, the customer's costs would go up and the utility would be unable to get the electric business. Something had to be done.

It seemed quite certain that if the utility could add the load of the isolated plant's generators to its own, the cost per unit of electrical output for the combined load would be much lower than for the utility's own load only, and that the margin of profit in the electrical end could support a loss on the steam end. It was equally evident that unless the customer was relieved of the expense of running his own boilers, the advantages to be gained by

shutting down the isolated plant and increasing the utility's electrical load could not be obtained.

There was but one course open—to admit but not welcome steam heating into the utility family. It was done reluctantly and piecemeal.

Assume the isolated plant's operating costs were $50,000 per year; electricity from the utility would cost $25,000. The utility would lease the boiler plant for $5000 per year rental and sign a contract to operate and maintain it, and furnish all necessary steam for heating or other purposes for $17,000—a total of $47,000. Some of these contracts ran for twenty to thirty years, and by 1920 steam was being supplied under some of these contracts for 10 cents per thousand pounds.

In this way the utilities in many of our cities took over the operation of the boiler rooms in a considerable number of isolated plants, acquiring the electrical load and a headache. Putting in a pipe line connecting two or three boiler rooms together, permitting one or more to be closed down, reduced the headache somewhat.

As these flat-rate contracts expired, the customer was put onto a meter rate; but when steam was sold at 20 cents per thousand pounds under the old flat rate, the meter rate could not increase this too much, or the customer would put his own plant back into operation and the highly desirable electrical load would be lost. So steam or rather condensation meter rates became more or less generally adopted, but they were designed primarily to retain the electrical load, rather than to make a charge commensurate with the cost, to say nothing of the value of the steam furnished. The headache was slightly reduced, but remained a dull, everpresent pain.

Gradually a few of the utilities began selling steam to customers along their lines, other than those they had taken on originally for the purpose of getting electrical load. The rates, however, were low, and steam was handled as a commodity rather than as a service—so many tons dumped into a customer's cellar to use as he saw fit, mostly ignorantly, inefficiently and wastefully. How far would the electrical industry have got if it had been handled on the same basis?

So district heating became the black sheep of the utility family. I have sat in meetings of utility associations and listened to one utility executive after another berate the steam heating industry, spreading the conviction that it is inherently and inevitably a losing business, but one which, unfortunately, they must put up with. Much of this feeling exists even today.

That such a feeling was not without foundation in the case of those companies where steam heating had been used solely for the purpose of acquiring electrical load, is shown in the following combined record of three companies for 1920:

TABLE I

1000 M Lb Sold	Avg. Rate	Coal, Ton	No. Cust.	Income	Operating Exp.	Operating Loss	Operating Ratio
2026	$0.57	$5.55	192	$1,153,954	$1,560,096	$406,142	1.35

That is, these three companies failed to pay operating expenses without taxes, interest or depreciation by over $400,000. This represents the penalty imposed upon the steam heating industry due to using it as a business getter for the electrical industry. One company that year sold 268,443 thousand pounds of steam under flat rate contracts to six customers whose individual use varied between 83,000,000 and 13,500,000 lb per year, for an average of 33.9 cents per thousand pounds, which did not even pay the coal cost as shown in Table II.

TABLE II—FLAT-RATE CONTRACTS

M Lb per Year	Revenue	Avg. Rate, Cents
83,800	$31,678.00	38
67,643	22,374.00	33
45,700	16,460.00	36
42,700	11,948.00	28
15,200	5,472.00	36
13,400	4,150.00	31
268,443	$92,082.00	33.9

Coal cost, $6.50 per ton. Assumed average evaporation, 8.5 lb.
Coal cost per M lb is $117.8 \times 32.5 = 38.3$ cents.
The average evaporation was probably closer to 7 lb.

That there was some hope for the steam heating industry, even in 1920, is shown by the record of one other company for the same year, selling steam to all the customers it could conveniently reach. This company's record was as shown in Table III.

TABLE III

1000 M lb Sold	Avg. Rate	Coal, Ton	No. Cust.	Income	Operating Exp.	Operating Net	Operating Ratio
1,905	$0.82	$6.69	2058	$1,568,102	$1,488,532	$79,570	0.95

It is interesting to note that for the three companies selling steam primarily for the purpose of getting the electrical load, the average use per customer was 10,550 thousand pounds, while for the single company it was 928 thousand pounds.

With the utilities entering the steam heating business in this way, placing practically all the emphasis on the acquisition of electrical load, with a vague hope that the losses on the steam heating would not be too heavy, little if any real salesmanship went into the sale of steam, resulting in the establishment of a low basis of value which for many years provided the standard on which rate systems were built up.

Independent companies, formed for the purpose of district heating during this period, were influenced in their rate structure by the standards set up by the utilities, while many of them sold steam at a flat rate per year which was not allowed to exceed the prospective customer's coal bill of the preceding year. Some such plants were poorly designed, poorly constructed—in fact, they were sometimes just promotional stock selling schemes, doomed to failure from this cause alone; some generated by-product electricity, became quite successful, and were bought up by the utilities.

The field of residence heating was entered, generally unsuccessfully, on account of the low density of business, the fact that the flat rates charged were made lower than the customer's own coal bill, heavy line losses and leaks, etc. The industry lacked the vision of the oil salesman who, ten to fifteen years later, sold expensive oil furnaces and high priced oil to residential users on the basis of its convenience, cleanliness and automatic features.

Growth of the Industry

There are no data available for the industry as a whole. In 1922 the National District Heating Association began reporting on the majority of the companies belonging to the Association, but the number of companies as well as the identity of the individual companies varied from year to year.

The N.D.H.A. reports show 32,399,366 thousand pounds of steam sold in 1930 by 44 companies. One

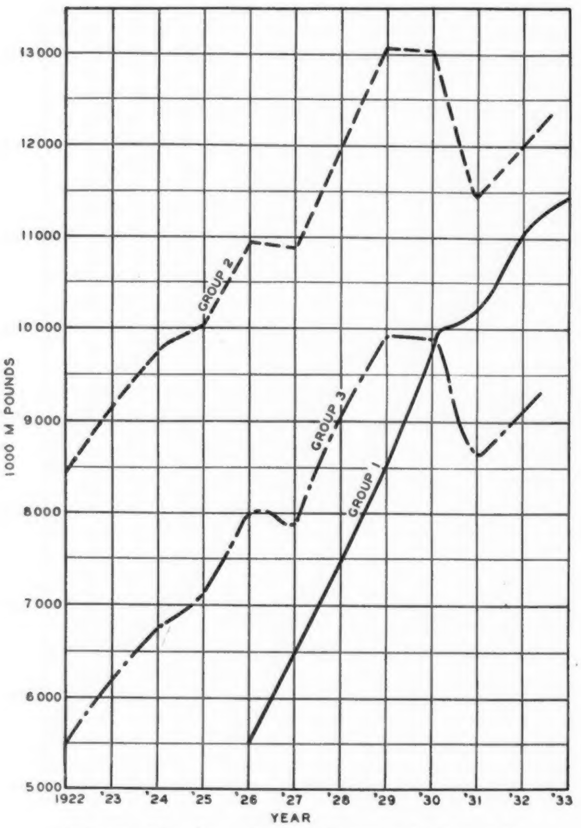


Fig. 1—Yearly sales for Groups 1, 2 and 3

Group 4, not shown, varies between 2954 million for 1922, 3198 million for 1929 and 2931 million for 1932

company alone, the New York Steam Company, sold almost one-third of this. The sales of this company grew from approximately three billion pounds in 1922 to ten billion pounds in 1930.

Omitting the New York Steam Company from the 1930 sales, N.D.H.A. reports show that 43 companies sold 12,361 million pounds in 1922 and 22,415 million pounds in 1930—an increase of 81 per cent in 8 years, or a compound rate of growth of approximately 8 per cent. Of the 43 companies originally reporting in 1922, only 17 reported under their original names in 1930, but many of the original companies had either been absorbed by other companies or had changed their names, and I believe the data are fairly accurate.

Table IV gives data on 17 companies which reported practically each year from 1922 to 1932, inclusive. This list includes some companies that were aggressively expanding their business; some that were distributing steam in a limited area where the saturation point had been reached, and where the company was opposed to expanding beyond this area; and some that were endeavoring to reduce their sales in order to reduce their losses. These are factors which have to be taken into consideration in an analysis of the mass figures published on district heating. One can hardly expect to see encouraging results in a business whose operators feel that the growth of the business means simply increased losses. It is equally true that including the figures for one overwhelmingly large and aggressively managed company distorts the results for the other companies. I therefore have shown the yearly totals for four groups of companies:

Group No. 1—Company No. 1
" No. 2—16 companies, Nos. 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 15, 20, 21, 24, 32, 39
" No. 3—10 companies, Nos. 2, 3, 4, 6, 7, 8, 11, 20, 32, 39
" No. 6—6 companies, Nos. 9, 10, 12, 15, 21, 24.

Table V shows the percentage of growth for the ten-year period, 1922 to 1932, which includes the depression years, and also for the eight-year period, 1922 to 1930, where the results are not distorted by depression conditions. Fig. 1 shows these figures in graphic form.

TABLE IV
Yearly Sales in 1000 M Lb of Steam for 17 Companies

Year	Co. No. 1	No. 2	No. 3	No. 4	No. 6	No. 7	No. 8	No. 9
1922	3,000.0	1,730.0	846.8	538.5	601.7	652.1	497.7	784.6
1923	3,600.0	1,856.7	950.0	607.6	830.0	730.6	574.6	750.0
1924	3,900.0	1,986.3	1,060.0	677.9	831.6	800.0	673.4	752.0
1925	4,400.0	2,048.3	1,176.0	692.8	941.2	870.2	687.6	770.3
1926	5,500.0	2,323.0	1,328.3	807.0	1,000.0	980.0	738.1	780.0
1927	6,304.0	2,128.5	1,268.1	900.0	1,070.8	1,088.0	675.8	802.7
1928	7,547.2	2,455.1	1,385.9	1,128.0	1,240.3	1,196.6	785.5	764.5
1929	8,590.8	2,834.7	1,340.7	1,309.2	1,310.9	1,195.2	802.5	828.3
1930	9,984.9	2,578.9	1,452.7	1,339.8	1,349.2	1,084.7	918.7	835.1
1931	10,146.4	2,129.6	1,283.7	1,238.5	1,031.6	1,023.7	800.7	772.6
1932	11,146.1	2,124.5	1,377.0	1,255.9	1,086.8	963.8	914.4	752.5

Year	No. 10	No. 11	No. 12	No. 15	No. 20	No. 21	No. 24	No. 32	No. 39
1922	852.7	190.1	469.7	359.6	244.1	276.6	210.4	106.3	87.0
1923	891.0	207.0	444.3	394.9	218.3	260.0	199.0	137.2	96.7
1924	904.6	213.7	487.3	401.3	230.0	253.1	201.3	152.8	117.0
1925	855.3	175.7	446.2	425.1	242.5	240.2	186.0	166.3	108.1
1926	790.8	225.5	455.0	477.5	296.9	246.7	191.8	189.9	129.8
1927	728.0	228.7	557.0	476.3	235.1	279.3	198.4	144.4	113.5
1928	720.7	262.5	464.4	464.4	270.0	295.0	202.4	202.4	121.6
1929	757.3	437.9	567.6	505.7	299.3	327.2	212.0	193.0	172.3
1930	794.1	492.6	556.6	464.9	328.8	309.4	219.5	182.4	144.3
1931	669.1	545.4	503.0	398.3	285.9	269.5	227.8	158.5	123.3
1932	752.8	710.0	488.5	423.5	323.7	284.0	230.0	155.1	160.9

Yearly Total Sales in 1000 M Lb for Groups Nos. 1, 2, 3 and 4

Year	Group 1	Group 2	Group 3	Group 4
1922	3,000.0	8,447.9	5,494.3	2,953.6
1923	3,600.0	9,147.9	6,208.7	2,939.2
1924	3,900.0	9,742.3	6,742.7	2,999.6
1925	4,400.0	10,031.8	7,108.7	2,923.1
1926	5,500.0	10,960.3	8,018.5	2,941.8
1927	6,304.0	10,894.6	7,852.9	3,041.7
1928	7,547.2	11,959.3	9,047.9	2,911.4
1929	8,590.8	13,093.8	9,895.7	3,198.1
1930	9,984.9	13,051.7	9,872.1	3,179.6
1931	10,146.4	11,461.2	8,620.9	2,840.3
1932	11,146.1	12,003.4	9,072.1	2,931.3

TABLE V
Per Cent Growth in Sales for Groups 1, 2, 3 and 4

10—for 10-yr period, 1922 to 1932
8— " 8 " " 1922 " 1930

Year Period	Group 1	Group 2	Group 3	Group 4
10	271 per cent	42 per cent	65 per cent	loss
8	232 per cent	55 per cent	80 per cent	8 per cent

Note the wide range in the size of the companies included in Group 3, varying from sales in 1930 of 2600 million pounds down to 144 million pounds. Also, note that from 1922 to 1929 or 1930 the following companies practically doubled their sales or better: Nos. 1, 4, 6, 7, 8, 11 and 39.

Effect of the Depression

District heating suffered less during the depression than either the electrical utility or artificial gas. Table IV shows that companies Nos. 1 and 11 increased their sales right through the depression period. In fact, two of the more aggressively managed companies spent several million dollars in 1930–31 and '32 extending their distribution systems and enlarging their plant facilities, in the belief that district heating offers an attractive field for development.

A comparison of the sales for 1929–30–31 and '32 for Groups 3 and 4, Table VI, gives the following percentage relations:

TABLE VI

Sales Changes 1929–30–31–32

Per Cent Change from Previous Year	Group 3	Group 4
1929 to 1930	0.24 per cent loss	0.56 per cent loss
1930 to 1931	12.6 per cent "	10.7 per cent "
1931 to 1932	5.0 per cent gain	3.1 per cent gain

The N.D.H.A. reports give the following comparisons of identical companies reporting in consecutive years:

TABLE VII

No. Companies Reporting	Years	Change	No. Companies Reporting	Years	Change
33	'28 to '29	Gain 11.4 per cent	43	'31 to '32	Gain 7.3 per cent
42	'29 to '30	Gain 3.8 per cent	38	'32 to '33	Loss 3.0 per cent
43	'30 to '31	Loss 7.0 per cent			

Rate Systems

Prior to 1920 many companies were selling steam on a flat-rate basis of a fixed price for the heating season or a flat rate per square foot of radiator surface or cubic feet of space. This system proved to be no more successful in the sale of steam than it had been in the sale of water or the sale of electricity for lighting.

Handicapped in the early years by lack of satisfactory metering equipment, efforts to develop such equipment had resulted by 1920 in the production of fairly satisfactory condensation and steam flow meters. The change from the old flat rates to meter rates then began to develop quite rapidly. With meters, operating companies knew what they were doing and could correct some of the errors of the past.

The price basis established under the flat rates previously used, made it very difficult to put into effect meter rate systems designed to give a satisfactory return; but about 1920 some of the more aggressive companies decided to increase their rates, even though they might lose a considerable portion of their load.

In 1920, data available show that four companies sold approximately four billion pounds of steam at an average rate of 69 cents per thousand pounds, with an operating ratio of 1.12, and an operating loss of more than $300,000. Three of these companies sold approximately two billion pounds at an average rate of 57 cents, an operating ratio of 1.35 and an operating loss of over $400,000. In the case of two companies, the fuel cost alone was greater than the income.

It was decided to boost rates and lose some of the business, and the rates for 1921 were increased from 18 to 77 per cent above the 1920 rates. Yet by 1923 the companies were selling more steam at the higher rates than they were selling in 1920, and the operating loss had been turned into an operating profit.

Table VIII gives the percentage relation for the different factors from 1920 to 1925, inclusive. Fig. 2 shows graphically the results for the four companies totaled, and the three companies totaled.

The year 1920 marked a turning point in the sale of steam, for it was at this time that the decision was reached to handle steam no longer as a commodity but as a service: to cooperate with the customer, give him expert advice, and inspection service to assist him in using steam more economically, and charge a rate commensurate with the value of the service rendered. It saw the beginning of rate systems designed to give the customer having a better than average yearly load factor,

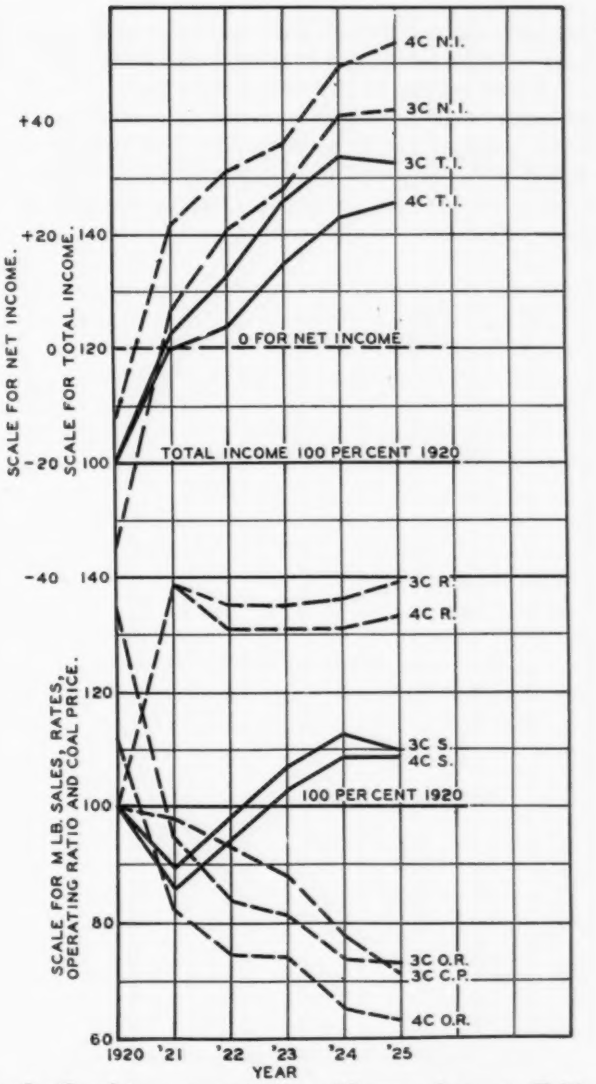


Fig. 2—Graphic representation of figures shown in Table VIII with increased sales under new higher rates

the advantage of that better load factor by permitting him to earn a lower than average rate by systematically controlling his maximum demand.

The loss of business was not as heavy as had been feared. The maximum loss by any company in 1921 was 17.5 per cent, and from this time on, all companies enjoyed a steady growth in sales except one, and this company suffered a permanent loss of 15 per cent of its 1920 sales.

Comparing 1925 with 1920, note that the three companies increased their average rates 39 per cent and their sales 10 per cent, despite the fact that the market price of coal to their customers as well as to themselves had decreased 28 per cent. In other words, the customer had come to the conclusion that although he could buy coal 28 per cent cheaper than in 1920, he was willing to pay a 39 per cent higher rate for steam. This does not, of course, mean that he paid 67 per cent more for steam service in 1925 than operating his own plant would have cost him. It does mean that the utilities' efforts to help him effect economies in his use of steam were bearing fruit, and that he had come to appreciate some of the more or less intangible values of the service rendered him.

The record of Company No. 3 is particularly striking. Despite a 77 per cent increase of rates in 1921, this com-

pany lost only 4 per cent of its 1920 sales and changed a 16 per cent operating loss into an 81 per cent profit. By 1925 it was selling 31 per cent more steam, at a 58 per cent higher rate in spite of a 40 per cent decrease in the market price of coal; total income had increased 106 per cent and net profit had gone from a $16^1/_2$ per cent loss to a 104 per cent profit expressed as a percentage of 1920 total income.

TABLE VIII—COMPARATIVE RESULTS OF 4 COMPANIES INDIVIDUALLY, THE SUM (4C) OF THE 4 COMPANIES, AND THE SUM (3C) OF NOS. 1, 3 AND 4 COMPANIES, FROM 1920 TO 1925, INCLUSIVE

M Lb Steam Sold as Per Cent of 1920 Sales

Co. No.	1920	1921	1922	1923	1924	1925
1	100	85.5	85.7	90	91	86
2	100	82.5	90.8	97	104	107
3	100	96.3	103	116	129	131
4	100	89.3	117	133	138	138
4C	100	86	94.5	103	109	109
3C	100	90	98.	107	113	110

Avg. Rate per M Lb as Per Cent of 1920

Co. No.	1920	1921	1922	1923	1924	1925
1	100	118	125	125	121	131
2	100	142	130	130	130	129
3	100	177	168	168	166	158
4	100	130	120	125	126	128
4C	100	139	131	131	131	133
3C	100	138	135	135	136	139

Total Income as Per Cent of 1920 Total Income

Co. No.	1920	1921	1922	1923	1924	1925
1	100	102	108	113	112	115
2	100	117	118	127	135	137
3	100	169	173	195	216	206
4	100	116	141	162	174	177
4C	100	120	124	135	143	146
3C	100	123	133	146	154	153

Net Income as Per Cent of 1920 Total Income

Co. No.	1920		1921		1922	
1	56.5	loss	30.0	loss	6.0	loss
2	5.1	profit	33.5	profit	37.5	profit
3	16.5	loss	81.0	profit	91.0	profit
4	10.5	loss	1.8	loss	2.1	loss
4C	12.0	loss	22.0	profit	30.5	profit
3C	35.0	loss	6.6	profit	21.0	profit
	1923		1924		1925	
1	1.6	loss	3.4	profit	10.0	profit
2	41.7	profit	56.0	profit	62.0	profit
3	103.0	profit	116.0	profit	104.0	profit
4	2.4	profit	34.5	profit	38.0	profit
4C	35.8	profit	49.5	profit	53.5	profit
3C	27.6	profit	40.8	profit	41.8	profit

Coal Price per Ton as Per Cent of 1920 Price

Co. No.	1920	1921	1922	1923	1924	1925
1	100	94.5	89	85	75	77
2	100	108.	93	89	75	69
3	100	93.	90	83	79	59
4	100	106.	106	98	85	78
4C	100	101.	92	88	78	71
3C	100	98.	93	89	78	72

Operating Ratio

Co. No.	1920	1921	1922	1923	1924	1925
1	1.57	1.29	1.05	1.01	0.97	0.71
2	.95	0.72	0.68	0.67	0.59	0.55
3	1.16	0.52	0.47	0.48	0.46	0.50
4	1.11	1.01	1.01	0.99	0.81	0.78
4C	1.12	0.82	0.75	0.74	0.65	0.63
3C	1.35	0.95	0.84	0.81	0.74	0.73

Fig. 2 indicates graphically the results of five years of operation under the new rates. After 1921 the rates remain practically constant. Sales, total income and net income continued to rise quite sharply until 1924, while the operating ratio and coal price dropped rapidly. These results would be even more striking if it were not for the inclusion of Company No. 1 which suffered a permanent loss of business and did not show an operating profit until 1924.

Five Lamps Per Person

As an index of lighting progress, statistics show that the American citizen consumes slightly more than five lamp bulbs per year. The next nation in the order of lamp usage is Denmark which uses up approximately 1.75 lamp bulbs per person per year. Most European countries use about 1.5 lamps per person.

Chevrolet to Install 650-lb Boilers

The Chevrolet Motor Company, Detroit, generates part of its power and purchases the remainder. It has certain process steam requirements, in addition to heating, among which are relatively large demands by the steam forges. At present there is installed a battery of 200 lb boilers which supply steam through reducing valves to the forges at 105 lb pressure and steam at boiler pressure to three 3500-kw mixed-pressure turbines. The latter also take exhaust steam from the forges at 8 lb gage and exhaust to jet condensers. Cooling water is supplied by a cooling tower.

To meet increasing production demands it has been decided to install a 7500-kw bleeder turbine-generator with the layout arranged so as to afford the most economical heat balance consistent with the given conditions. Steam for the new turbine will be supplied at 650 lb, 725 F by two new boilers each having a rated capacity of 120,000 lb per hour but with the pulverized fuel burning equipment arranged so that either boiler alone can produce up to 170,000 lb of steam per hour. The turbine will exhaust to a surface condenser, served by the cooling tower, and will also bleed steam at 105 lb to the forges and to a high pressure feedwater heater. A pressure reducing valve and desuperheater will be provided on the 650-lb line so that live steam may be supplied from the new boilers direct to the forges when necessary if the larger turbine be shut down.

Plans for the new installation have been drawn up by Albert Kahn, Inc., Architects and Engineers, Detroit, under the immediate supervision of Messrs. J. Gordon Turnbull and F. K. Boomhower, who were identified also with the earlier installation at the Chevrolet Motor Company. This plant represents an excellent combined central station and industrial plant service.

New Steam Generating Unit Installed in Short Time

Designed, delivered, erected and placed in operation in less than 90 days is the record of the new boiler and pulverized fuel installation at the plant of the North Carolina Finishing Company, manufacturer of rayon goods at Yadkin, N. C.

Steam was previously furnished by several hand-fired boilers two of which were removed to make space for the new unit. Production committments made it necessary that the additional steam be available the first of September.

On June 10 a contract was signed with Combustion Engineering Company, Inc., for a two-drum boiler to deliver continuously 60,000 lb of steam per hour at 425 lb pressure and 550 F total steam temperature at $85^1/_2$ per cent efficiency. The unit has 8060 sq ft of steam heating surface with 3-in. front tubes and 2 in. rear tubes and both top and bottom drums are fusion welded. A plate type air heater of 8650 sq ft surface is provided and the unit is completely steel encased.

Pulverized coal is provided by two Raymond Impact Mills.

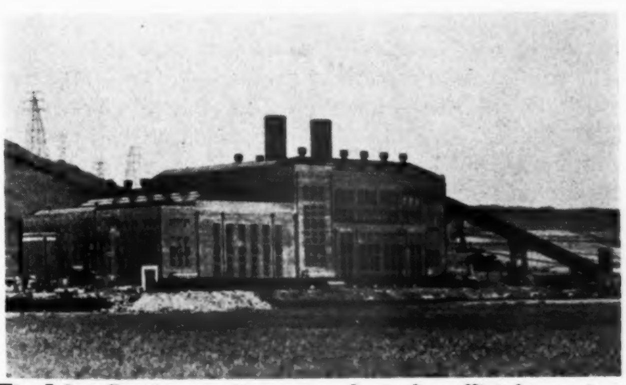
Through the cooperation of all parties concerned the schedule was met and the boiler was under steam on Monday, September 2.

Further Details of the Tir John Power Station

Tir John, the latest British power station, located at Swansea, South Wales, was officially opened on June 20. A preliminary description of the boiler plant and the fuel burning equipment to burn pulverized anthracite duff appeared in COMBUSTION, September 1934. The present article gives further details on the station as a whole and describes certain unusual features.

THE Tir John Station of the Swansea Corporation was originally conceived about 1924, to meet the increasing electrical load for which the old station, in 1900, was obviously inadequate. The site chosen for the new station was to the east of Swansea, South Wales, on what is known as the Crymlyn Bog, which is really an old river bed filled up with alluvial deposits. Work on the station was started in September 1931, and it has taken nearly four years to complete the first section of 60,000 kw capacity which was officially opened on June 20 of this year.

One of the problems that had to be faced was that of bringing the circulating water to and from the station, and several alternative schemes were considered. Rock was found 14 ft below the surface, and it was finally decided to tunnel through the rock at a fairly deep level—240 to 300 ft—from the station to the bay about 900 yards distant. At the station end, 14-ft diameter shafts were sunk almost entirely in the rock, but at Kings Dock on the bay a peculiar problem arose, since the shafts had to be sunk nearly 200 ft through the alluvial deposit, gravel, etc., which necessitated special treatment. Ultimately, the ground was frozen by the following method: Separate holes were bored vertically outside the actual shaft, and in these steel pipes were placed. The lower ends of these pipes were closed, and refrigerated brine was circulated through them. When the ground was sufficiently hard, a solid ice wall was formed, and the core of silt and other deposits could be excavated without trouble. The two shafts at the station end of the tunnel are lined with concrete while those at the dock are lined with cast iron from the surface through the water-bearing strata into the rock, below which they are concrete lined.



Tir John Station as it appeared at the official opening

The section of the station which has now been opened is only one-fourth of the projected ultimate capacity. It includes two turbine-generators, each of 30,000 kw capacity, and four boilers each of 240,000 lb per hr maximum evaporation. The turbines are of the Parsons pure reaction design, of the two-cylinder tandem type operating at 3000 rpm with steam of 600 lb pressure and 825 F.

Steam-Generating Equipment

Of particular interest is the steam-generating equipment which is designed to burn anthracite duff in pulverized form. This fuel has a volatile content of 6 to 8 per cent, 74 to 80 per cent carbon, and moisture and ash of approximately 4 and 14 per cent, respectively.

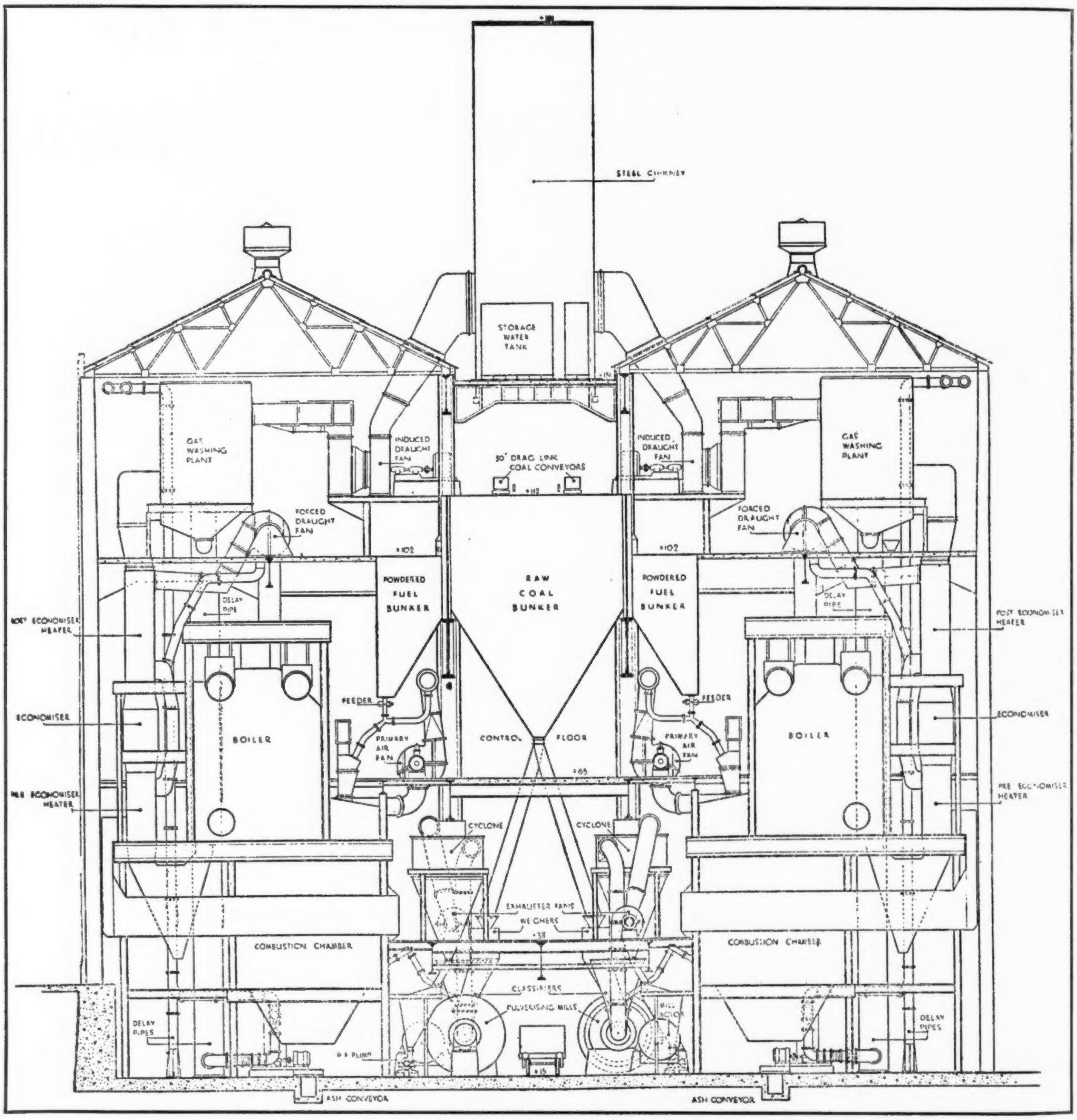
The four units installed each have a heating surface of approximately 16,500 sq ft, designed for a normal evaporation of 200,000 lb per hr and a maximum of 240,000 lb per hr at 625 lb pressure, with a final steam temperature of 850 F. They are of the Combustion "steam generator" three-drum type with water-cooled combustion chambers, and each is fitted with a superheater, an economizer of the Foster gilled tube type and an air heater.

The M.L.S. superheaters are of the single-pass ball-joint type, and have dampers by which the gases may be bypassed in different proportions, so as to maintain an approximately constant temperature of 850 F down to about half load.

The arches, into which the burners are mounted, are of the Detrick suspended construction.

Each economizer has approximately 7000 sq ft of surface and they are designed for the comparatively small rise of about 38 F from the feed temperature of 350 F at the normal load of 200,000 lb per hr.

Another interesting feature is that the air heaters are of the twin type, one section being located before the economizer and the other after it. These air heaters are of the plate type with a total heating surface for each boiler of about 70,000 sq ft; approximately 44 per cent of this being ahead of the economizer, and the remainder between the economizer and the induced-draft fan. The final air temperature is calculated to reach about 700 F. As the combustion chambers are mostly water cooled



Section through boiler room of Tir John Station

and as the volatile of the fuel ranges from 6 to 8 per cent, it is evident that highly preheated air is essential. The heat liberation in the furnace is approximately 17,000 Btu per cu ft per hr at normal load.

Because of anticipated difficulties in lighting the fires with such a low volatile fuel, auxiliary oil burners have been fitted, two being mounted below the burner arch and two near the bottom at each side of the furnace. These oil burners are of the compressed-air type, capable of supplying about 500 lb of oil per burner per hour. The fuel oil pumps are motor-driven and are of the rotary displacement type, a constant pressure being maintained in the circulating system by means of a regulating relief valve set to any desired pressure.

The mills which are of the Hardinge type with classifier, cyclone and exhauster fan, contain 28 tons of steel balls and are each capable of grinding ten tons of anthracite duff per hour, conforming to the analysis given below. They operate on a closed circuit, so that the operation is under a partial vacuum, and are designed to pulverize this amount of coal to a fineness of 85 per cent through 200 mesh, I.M.M. sieve, and 99 per cent through 100 mesh. The grading of the raw coal is as follows:

	Per cent
Through 50 mesh	30
Through 20 mesh	55
Through 10 mesh	83
Through 8 mesh	95

The coal has a proximate analysis as follows:

	Per cent
Moisture content	4
Volatile matter	6 to 8
Carbon	80 to 74
Ash	14
Melting point of ash	2460 F

The ultimate analysis shows 76.46 per cent carbon and 2.95 per cent hydrogen.

Each mill is driven through single helical gearing by a 425-hp motor of the slip-ring type equipped with rotor speed regulators.

Four Lopulco pulverized fuel transport pumps are provided, one to supply each pulverized fuel bunker. The pipe lines are so arranged that any transport pump may supply any bunker, and in the event of one or more mills not being in operation, the remaining mills and pumps may be so controlled that they will serve all the bunkers.

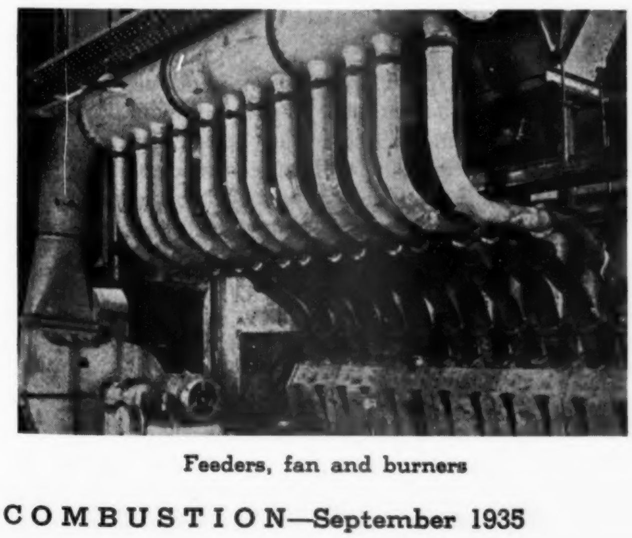
Pulverized coal coming from the cyclones to the feed inlet of the transporters is conveyed by a screw feed to the transporter outlet, where, by means of an air blast, the fuel is carried along the transport lines to the bunkers. Control of the fuel along the pipe lines is rendered possible by an arrangement of individually operated switching valves, and by this means any desired section of piping may be isolated from the remainder.

The raw coal is fed to the pulverizers through automatic weighers each designed for 15 tons per hour. The pulverized fuel bunkers are arranged at a high level, for feeding direct to the twelve vertical burners, these burners being fitted in pairs and served by duplex feeders. The primary air fan in each case draws warm air from the air heater, located before the economizer.

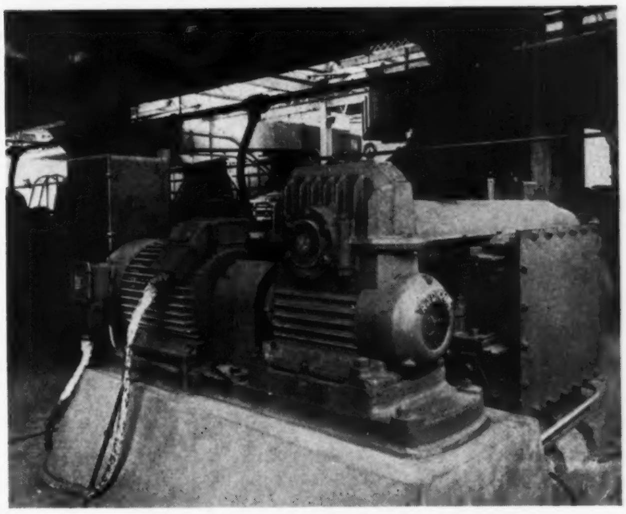
Gas Cleaning Plant

Dust and acids in the flue gases leaving the boilers are removed by Howden-I.C.I. flue gas scrubbers,[1] no other means of dust extraction from the gases being installed. These scrubbers are designed for the removal of 96 per cent dust and 96 per cent sulphur, and in addition will remove 90 to 95 per cent of the hydrochloric acid and 60 to 70 per cent of the nitric acid in the flue gases. The coal contains from 0.6 to 1 per cent sulphur, and up to 13 per cent ash.

[1] For a detailed description of the Howden-I.C.I. system see COMBUSTION, April 1935.



Feeders, fan and burners



One of nine sets of "Radicon" reducers for driving conveyors

A unit system of scrubbing is employed, each of the four boilers being equipped with a scrubber located immediately after the air heater. There are two nests to each unit and for low boiler loads either of the nests can be cut out. The scrubbers each have their own delay tanks, the latter taking the form of a tall vertical chamber extending from the washer floor to the basement. The liquor is recirculated by two high efficiency axial flow pumps per scrubber, designed for pumping 8300 gal per min against a head of 30 ft. These pumps are in the basement and are driven by squirrel-cage motors. The plant is designed for a concentration of suspended solids in the recirculating liquor of about 13 per cent, and this is kept constant by extracting continuously a quantity of the liquor. The exact amount of extracted liquor depends on the coal analysis, and is approximately 60 gal per min at full load. The purge is discharged with the ash from the boiler and economizer hoppers into a swirl pit at ground level. Effluent and ash is then discharged into the bog, some distance from the boiler house.

Approximately 80 gal of make-up per minute is used by each scrubber at full load, but this depends on the purge quantity and gas temperature. The water is drawn from the bog by centrifugal pumps at a point remote from the effluent and ash disposal point.

Lime is the neutralizing agent used. It is added continuously to maintain a pH between 6.2 and 6.4 in the recirculating liquor leaving the grid packing. A milk of lime preparation plant is provided, which is capable of slaking 2 tons of burned lime per hour. There is a storage capacity of 30,000 gal of milk of lime in two stock tanks. The liquid is circulated through a ring main in the boiler house and the feeds to the scrubbers are taken from this ring. The control of the lime addition is automatic, by pH recorders, while that of the purge is manual from readings of continuous density recorders.

The draft equipment for each unit consists of a single induced-draft fan and two forced-draft fans, all of the vane-controlled type. The primary air fans have also been supplied by James Howden and are of their turbo-vane type. Each forced-draft fan is capable of delivering to the preheaters 47,000 cu ft of air per minute and is

driven by an a-c motor of the commutator type, running at a maximum speed of 985 rpm, with a speed variation of 50 per cent.

The induced-draft fans are driven by two-speed a-c motors. Each fan has a capacity of 118,400 cu ft per min of flue gas at a temperature of 175 F. Each of the primary air fans has a capacity of 25,000 cu ft of air per minute, at a temperature of 700 F.

Coal Handling Equipment

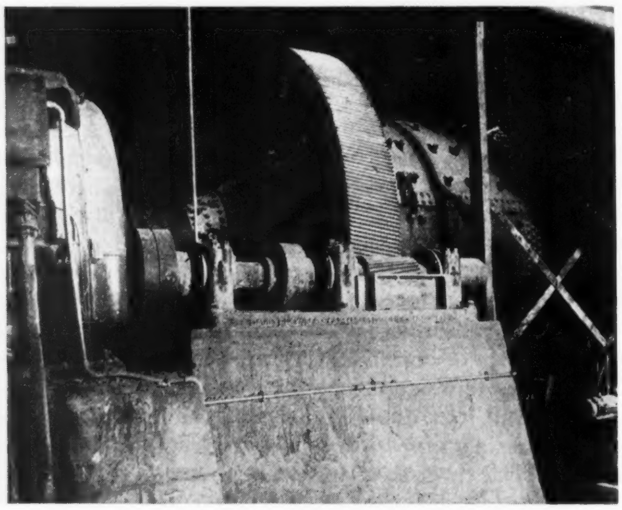
This comprises two weigh bridges, two truck tippers, a receiving hopper, a coal-dust extraction plant, mechanical conveyors, elevator and a drag line scraper installation. The coal is received at the station in standard railway cars which are run by gravity to the first weigh bridge where they are discharged into the main hopper, and then to the second weigh bridge to obtain the actual coal weight. After weighing they run by gravity down to an empty siding.

From the receiving hopper the coal is fed to two inclined belt conveyors which discharge into a receiving hopper in the boiler house, from which it is transferred to enclosed scraper conveyors delivering to the raw coal bunkers. Coal can also be delivered to reserve storage by means of a bucket elevator, and distributed over the reserve storage by means of a drag line scraper. The plant is designed for an average operating cycle of 6 min per car when operated by one man.

Ash Handling Plant

Scraper conveyors have been installed beneath the boilers. These deliver the clinker and ash to a sump to which the effluent from the gas washing plant is also delivered. From the bottom of this sump, the clinker and ash is removed by three Hydroseal vertical-spindle pumps. It should be mentioned that before entering the sump the clinker from the furnaces is passed through a crusher.

There will be a considerable variation in the quantity of material delivered to the sump depending on the number of boilers working, and on the gas washing plant. To deal with this variation, the motors driving the pumps are arranged for two-speed operation, and in order to maintain a minimum velocity in the discharge lines from the pumps, one of these discharge lines is 5 in. and the other 6 in. By selecting the right combination of pump speed, number of pumps and size of pipe line, any operating condition can be dealt with.



One of the mill drives

The station has two raw coal bunkers, each having a capacity of 700 tons, and also four pulverized fuel bunkers each having a capacity of 100 tons. These bunkers are lined with two inches of reinforced Gunite.

Turbine-Generators

As previously mentioned, two 30,000-kw, 3000-rpm units are now installed. The most economical load of these machines is 24,000 kw and the guaranteed steam consumption is 9534 Btu per kw-hr. The turbines have stainless steel blading, while the stator castings are of mild steel, electrically welded. Four-stage heating is employed, the condensate being heated to the final temperature of 350 F.

The core conductors are of Parsons patented triple concentric type of stranded cable, the individual wires being insulated with asbestos and spiraled to eliminate eddy currents. The rotors are machined from solid forgings of high grade mild steel, the radial slots to receive the excitation windings being milled out of a solid. The windings are of copper strip, the coils being accurately formed on a coil forming machine before being placed in the slots. The rotor insulation is micanite, and the end windings are securely spaced with bakelized heat-resisting asbestos packings.

The exciters are driven direct by the main units. That is, each main armature together with its auxiliary armature are mounted on the same shaft and are driven from the turbine rotor shafts through a flexible coupling.

The bed plates of the turbine-generators are of electrically welded mild steel.

Condenser Equipment

Each of the two Vickers Armstrong condensers are of the two-flow regenerative type, having a cooling surface of 30,000 sq ft. The double shells are of mild steel welded construction, and are so arranged that one half of the tubes may be opened up for cleaning while the other half remains in commission.

Four Weir three-stage steam-air ejectors and surface inter-coolers are fitted, and in addition there are six sets of steam-air exhausters for rapidly increasing the vacuum.

Feed Pumps

The main feed pumps consist of four booster pumps working in conjunction with four main Weir pumps, all electrically driven. Each of the booster pumps is capable of delivering 300,000 lb of feedwater per hour, and handles the feed at 216 F against an absolute pressure of 230 lb per sq in. They are direct coupled to 125-hp a-c motors running at 1450 rpm. In addition, a steam turbine driven feed pump is supplied as a standby.

The station was designed under the supervision of J. W. Burr, electrical engineer to the Borough of Swansea, and the consulting engineers were Messrs. Preece, Cardew & Rider (for plant and superstructure) and Sir Cyril Kirkpatrick & Partners (for tunnels and foundations).

SPONTANEOUS COMBUSTION in Coal Storage Piles

By ELMER L. LINDSETH and F. J. LEONHARD
Production Department, Cleveland Electric Illuminating Co.

The properties of slack, high or medium volatile coals make them susceptible to spontaneous heating in storage unless certain precautions are taken. The authors review the conditions contributory to such of coal in storage and show what steps may be taken to guard against it; also how to detect an undue rise in temperature.

THE tendency of coal to burn in storage is a disadvantage measured not only by the value of the coal so consumed but also by the labor required to cope with fires, by the resulting reduction in the safe storage capacity of a given site and by the hazard created when hot coal, with its attendant gas, is admitted to a building.

Properties of the coal and conditions of storage jointly determine whether spontaneous combustion will develop. Clean, lump coals usually present no problem, as their properties are inherently unfavorable to spontaneous heating. On the other hand, the properties of slack, high or medium volatile coals make them susceptible to spontaneous heating unless storage conditions are definitely inhibitive. However, it is often necessary to store these coals known to be troublesome. Therefore, in practice the question is often not so much "What kind of coal should we store to avoid fires?" as it is "How may we safely store coal which we know has a strong tendency to heat?"

In searching for an answer to this question it is helpful to keep in mind the general mechanics of spontaneous combustion. Coal in the presence of air absorbs oxygen with the evolution of heat at a rate which is hardly perceptible at ordinary temperatures but, in susceptible coals, becomes considerably above 150 to 200 F (1).[1] During this absorption of oxygen the evolution of carbon dioxide is low in relation to the heat generated (2). Moreover, coal may absorb carbon dioxide to a certain extent with considerable evolution of heat (3). Fine coals, by presenting a greater surface for oxygen absorption, tend to heat more readily than lump coals. The fresh surfaces of newly mined and recently crushed coals absorb oxygen and generate heat more rapidly

[1] Numbers in parentheses refer to the bibliography at the end of this article.

than old surfaces, which have been "satisfied" with oxygen (4). Higher volatile coals show a greater tendency to heat than do lower volatile coals (5). Pyrite has been found to promote heating both by itself oxidizing and so generating heat (5) and by swelling and breaking the coal to expose fresh surfaces (6). Moisture probably encourages heating by aiding catalytically in the oxidation of coal and pyrite (5) and, upon freezing, to break the coal and expose fresh surfaces (5). Spontaneous heating may likewise be initiated by the storage of hot coal, which has a higher rate of oxygen absorption, hence a higher rate of heat evolution and a consequent greater tendency toward a cumulative temperature rise than cooler coal. Spontaneous heating may likewise be accelerated by the application of external heat such as that furnished by the oxidation or decay of such foreign substances as oily rags and organic matter which in themselves are highly susceptible to spontaneous heating.

Heat Accumulation Builds Up Temperature

Heat generated, due to the foregoing causes, either escapes from the coal mass or accumulates. In the latter case it raises the temperature of the coal, thus further increasing its rate of heat generation and raising the temperature still faster. Once under way, this temperature rise continues until the coal reaches the kindling point. Whether the heat resulting from the slow oxidation at ordinary temperatures escapes from the coal or accumulates to set in motion a "runaway" temperature rise, depends entirely upon the ease with which heat may be dissipated from the region of its origin. Heat dissipation from within a pile is promoted by a low ambient temperature and by adequate provision for heat flow from the interior of the pile to the surroundings. Low ambient temperature is attained through the avoidance of external sources of heat such as pipes, tunnels, sewers, flues, etc., either beneath the pile or in close proximity. Heat flow from the interior may take place by conduction through the coal to the surface, whence it escapes by convection and radiation, by conduction to the ground or by convection to air passing through the interior of the coal mass (ventilation). Heat flow from the interior by conduction is encouraged by restricting the height and width of the piles so as to limit the distance the heat must be conducted and by compacting the pile to reduce voids and increase conductivity. Heat flow from the interior by ventilation is facilitated by limiting height and width of piles and by providing interior passages.

Briefly then, spontaneous combustion in a coal storage pile results when the rate of heat generation exceeds the rate of heat dissipation. This excess heat is utilized in raising the temperature of the coal, which in turn oxidizes and generates heat at a still greater rate, thus accelerating the temperature rise toward the kindling point. Whether or not this cumulative temperature rise occurs in a given pile depends upon which of the following two expressions describes the conditions obtaining in the pile:

1. Rate of heat generation is equal to or less than the rate of heat dissipation. (Safe condition—no fires)
2. Rate of heat generation exceeds the rate of heat dissipation. (Unsafe condition—temperature rise and ultimate fire)

Factors which affect the left side of these expressions are coal temperature, coal type, foreign matter, oxygen supply, surface area exposed to oxygen, degree to which coal surfaces are satisfied with oxygen and catalytic conditions. Factors affecting the right side are coal temperature, ambient temperature, pile size and shape, heat conducting properties of coal and internal ventilation.

Only two methods are available for preventing spontaneous combustion: First, by increasing the rate of heat dissipation; second, by reducing the rate of heat generation. Investigators of the problem have increased the rate of heat dissipation by,

1. Heat removal from the interior by conduction.
2. Heat removal from the interior by ventilation (i.e., cooling by air circulation through the coal mass).

Investigators have reduced the rate of heat generation in a given coal through restriction of air supply by,

1. Under water storage.
2. Prevention of segregation.
3. Compacting.

Heat removal by conduction occurs naturally when the heat generated within a pile is conducted by the coal to the surfaces of the pile whence it is dissipated by convection to the air, or by conduction to the ground or floor on which the pile is built. This natural heat removal by convection is an effective deterrent to heating only if all portions of the coal mass are sufficiently near the surface. The practical result of this is that a pile which would otherwise heat must be made shallow or narrow. This is a serious handicap because it is wasteful of ground space. Cooling by water circulated through pipes built into the pile has been proposed but the cost and resulting interference with reclaiming of the coal make this impractical.

Heat removal by ventilation consists of encouraging air circulation within the pile to remove heat by convection. Any loosely packed pile is protected by natural ventilation to a limited extent. Experience has shown that fires in such piles usually start at depths of from 2 to 10 ft (5) (7) which suggests that above this point heat can be dissipated by ventilation and conduction to the surface as fast as it is formed. From this it appears that such piles could be safeguarded by natural ventilation and conduction by being limited to a depth of from 2 to 10 ft—a practice wasteful of space. Artificial ventilation is dangerous because if it is insufficient it will seriously aggravate the condition it is supposed to prevent.

In Great Britain successful fire prevention has been accomplished by building perforated iron or earthenware pipes 3 to 4 in. in diameter into the coal mass vertically, one pipe per 300 sq ft of horizontal surface, with the further specification that the height of pile be limited to 10 ft (8). In Canada pipes are sometimes driven into the coal and then removed, leaving holes for easy access of air (5) (9). This procedure in one instance reported allowed the height of piles to be increased from 10 up to 14 ft with safety but required one hole for every $1^1/_4$ tons of coal (9).

Suppression of oxidation by restriction of air supply seeks to reduce the rate of heat generation to such a low value that natural heat dissipation, unaided by special precautions for cooling, is sufficient to prevent a serious temperature rise.

The most thorough restriction of air supply is accomplished with under-water storage but in the majority of cases high initial cost precludes the use of this method.

Entrance of air into coal piles containing small coal sizes can be virtually eliminated if proper precautions are taken to prevent segregation of coal sizes and to compact the coal mass. Segregation is likely to occur when a pile is built without the exercise of special precautions and the frequent result is a mass of easily oxidizable fines surrounded by lumps which, through their interstices, allow access of air sufficient to encourage oxidation but insufficient to remove the heat developed. Segregation may be controlled by building the pile in horizontal layers, the thinner the layers the more homogeneous the pile. Compacting the coal mass to close air passages and to improve heat conducting and water shedding properties has been practiced with quite general success.

A notable example of the use of layer built and compacted piles is the method of storage employed by the Philadelphia Electric Company (10). The practice of this company is first to prepare the ground by covering with ash or dry earth and rolling hard. Coal is then dumped and spread in 2-ft layers with a 2-ton caterpillar tractor and scraper. Each layer is then packed with a roller to a density of about 65 lb per cu ft. (Density of the loosely piled coal is 45 to 50 lb per cu ft.) In this way successive layers are put down until the flat top of the pile is only wide enough for the tractor. At this point loose coal is trimmed from the edges of the base with a clamshell bucket and dumped at the top.

Practical Methods and Precautions

As each case encountered in practice presents a different set of problems, any attempt at a universal solution is futile. The alternative is to recognize the methods, precautions and conditions which tend to suppress spontaneous heating and in each particular case to take judiciously the steps necessary to permit the safe storage of the required amount of coal in the available space with a minimum outlay for equipment and labor. As a guide the following suggestions are given:

Storage Site—Unfavorable conditions of the site may counteract all precautions taken in the actual building of the pile. The ground should be level, smooth, nonporous and clear of all vegetation and other foreign matter such as paper, rags, waste, straw, wood, manure, etc. Railroad tracks under a pile may provide detrimental air passages. Rolling of the ground is desirable, especially near tidewater, where the ground may have a tendency to "breathe" with the tides. A pile should not be built on tiled ground, although drainage around the edges is desirable. The pile should not be subjected to external heat from pipes, tunnels, ducts, flues, sewers, etc., either beneath the pile or in close proximity. Piling of coal against walls and fences or around structural members and pipes is undesirable because crevices at the surfaces of contact may permit the entrance of air and the concentration of rain water (7). Wooden structures, being themselves combustible, increase the fire hazard.

Condition of the Coal—Coal conditions known to provoke spontaneous heating should, of course, be avoided or corrected wherever possible. High volatile content and small coal size are eminently conducive to heating and fire. It is advisable to avoid storing coal in very wet weather and it is almost imperative that the coal be not above atmospheric temperature at the time of storage. Coals high in moisture and sulphur have shown increased tendency to heat. Coal freshly mined or crushed is more susceptible to heating than after it has aged for two or three months. This aging may be accomplished through temporary storage in low piles. Alternate wetting and drying or freezing and thawing encourage heating by breaking the coal and exposing fresh surfaces to oxidation. Such foreign matter in coal as paper, rags, wood, straw, etc., are themselves susceptible to spontaneous combustion and so should be avoided. Coal which passes the first year without heating will probably store indefinitely because after this period the surfaces are virtually "satisfied" with oxygen.

Piling of Coal—In the building of storage piles, the danger of ultimate fire can be lessened by minimizing breakage of coal in handling, by prevention of segregation, by compacting and by limitation of the height.

Minimizing breakage of coal in handling requires various precautions, depending upon the type of equipment. Breakage during handling by a clamshell bucket can be reduced effectively if the bucket is always lowered as far as possible before it is opened.

Prevention of segregation is accomplished by building the pile in layers from 2 to 4 ft thick. A refinement is to scrape each layer to present a smooth surface for the next.

Compacting is carried out by compressing each layer before the next is added and can be accomplished in a variety of ways. Hand tamping, while usually too laborious for general compacting, is useful for packing the coal around any structural members, walls, etc., against which the coal may be piled. In large-scale storage the tractor and the tractor-drawn roller have shown themselves to be economical. With a drag scraper system a roller may be substituted for the drag. A conventional motor truck may be used with success. At least one operator, after putting down a layer with the crane, substitutes for the clamshell a $2^1/_2$-ton steel and concrete weight, which is hoisted several feet above the coal and dropped (3). A still simpler method is to drop the full closed bucket several times at the place where it is to be dumped until the area to be covered is flat and hard.

Limitation of the height of piles opposes heating tendencies by facilitating heat dissipation from the interior. The safe maximum height depends upon the properties of the coal and upon the degree to which the other conditions of storage are effective in suppressing the generation of heat. Another reason for height limitation is the convenience in digging out any fires that may develop. Fifteen feet is usually a safe height for layer built, uncompacted slack piles.

Fires—It is quite generally agreed that once a fire has started the only positive remedy is to dig it out promptly and either quench it directly or use the coal. Water poured on the exterior of a pile will, if it penetrates, form a protecting cake around the hot spot and prevent water from reaching the fire.

Detection of Heating in Coal Piles—As fire is usually the result of a gradual temperature rise, it is possible to obtain advance warning by routine observations. Hot spots in advanced stages are revealed by the odor of the gas evolved, by shimmering in the atmosphere above the pile, by the appearance of smoke or steam and by the melting of snow.

A more exact and sensitive method of locating hot spots and at the same time a means of estimating interior temperatures is to insert through the coal mass a rod or a rod and chain within a pipe permanently installed in the pile, leaving this for a period of time, withdrawing and feeling it over its entire length.

Since there is a more or less definite temperature at which coal starts to heat spontaneously and rapidly (i.e., the critical temperature) quantitative interior temperature measurements are of value. For some low-rank coals the critical temperature is about 150 F (5). Coal at or near this temperature should be watched carefully and, if the temperature continues to rise, should be dug out and quenched or immediately used. For the measurement of the interior temperature of coal piles it has been found convenient to lower a maximum-reading thermometer on a cord down a pipe driven into the coal, leaving it for the required time, and withdrawing. Another successful method consists of driving a pipe containing a thermocouple into the coal and measuring the temperature with a potentiometer. Such readings taken on 10- to 20-ft centers have been found to provide a useful temperature survey. If temperatures between 130 and 150 F are detected, the coal adjacent to these readings should be surveyed with readings on about 5-ft centers.

Summary

The foregoing methods and precautions for the storage of small-size coals which contain considerable volatile matter or sulphur can be reduced to the following rules:

1. Avoid (as far as possible) storing newly mined and freshly crushed coal, wet coal and coal containing foreign combustible matter.
2. Avoid storing hot coal.
3. Store on smooth, non-porous ground cleared of foreign matter.
4. Avoid piling against or around structures.
5. Avoid breakage of coal going into storage.
6. Avoid segregation of fines.
7. Exclude air by compacting.
8. Limit height of piles as necessary.
9. Inspect piles for fires and heating regularly.
10. If hot spots develop, remove hot coal.

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Versatility of Traveling Grate Stokers

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A wide variety of coals can be burned on traveling or chain-grate stokers. These are dealt with separately, and the furnace design and type of arch best suited to each fuel is discussed. Representative performance for each case is included.

THE modern forced-draft traveling or chain-grate type of stoker is a most versatile fuel burner. It will easily handle a wider variety of fuels than any other type of stoker. It is simple to operate, flexible and most efficient when provided with a furnace of proper design. Because of these inherent characteristics it is necessary to give serious consideration to its use whenever a stoker installation is contemplated. Of course, it does have some limitations and in these cases the underfeed stoker is then the type of machine to use.

The fuels commonly handled on the forced-draft traveling or chain-grate stokers are: anthracite, semi-anthracite, bituminous and sub-bituminous coals, lignite and coke breeze. In order to give proper consideration to design and operation, as effected by the widely differing characteristics of these fuels, they will be treated separately in this discussion.

Burning Anthracite

The burning of anthracite is practically limited to the forced-draft traveling grate stoker. In fact, it was for the burning of the smaller sizes of anthracite that this type was originally developed. Its adaptation to the use of other fuels followed.

Culm banks, mountains of fine fuel, formerly considered as necessary waste in the mining and preparation of anthracite for domestic and hand-fired industrial furnaces, challenged the ingenuity of the experimenter and the inventor. The earliest experiments developed four fundamental design factors which are still applicable to every modern installation. These are:

(a) The fuel must be fed to the furnace continuously in a uniformly thin bed.

(b) Heated refractory surfaces, in close proximity to the fuel bed, are required to maintain prompt and satisfactory ignition of the incoming "green" fuel.

(c) The fuel supporting surface must consist of small individual elements of the overlapping end type, so designed as to give a free air space of from five to ten per cent, and at the same time minimize the possibility of "fines" sifting through the grate surfaces.

(d) The air supply to the grate should be zoned and controlled as to pressure and volume.

Anthracite, because of its low volatile matter and high fixed carbon content, is difficult to ignite rapidly. Because of this fact, it is necessary to provide a refractory arch to shield the ignition end of the furnace from the cooling effect of the heat absorbing surface, that might otherwise "see" the incoming fuel. Ignition of the fuel bed is thus obtained by radiation from the heated refractory surfaces in the furnace. The length of the arch must therefore be sufficiently great to insure a constant supply of radiant heat.

All of the furnaces in the earlier installations were of the front-arch design, similar to that shown in Fig. 1. There are two serious objections to furnaces of this type—the first is that there is a tendency for the gases to stratify, and second high carbon loss in the ashpit and fly ash.

The stratification of gases, in many cases, resulted in continuous combustion in the boiler passes. As a result there was serious loss in efficiency due to high stack temperatures. Furthermore, superheated steam temperature was erratic and in many cases the superheaters and their supports were damaged, due to excessive temperature of the gases. Experiments developed the fact that this continuous combustion may be considerably reduced, and often entirely eliminated by the application and proper use of over-fire air. The effect of over-fire air is to break up stratification in the furnace, mixing the lean and rich gases, and thereby causing combustion to be completed before the boiler surfaces are reached.

High carbon loss in the ashpit and fly ash were the cause of inconsistent efficiencies in the earlier installations. While the furnace design was responsible for this, in a great measure, there was still another factor to be considered. Commercial No. 3 buckwheat was presumed to be screened through a $^3/_{16}$-in. round hole screen and passed over a $^3/_{32}$-in. screen. Investigation developed the fact, however, that a varying percentage of undersize, all passing through a $^3/_{32}$-in. screen, had a decided influence on the results that could be obtained with a given installation. When this undersize exceeded 25 per cent, the efficiency began to fall rapidly and at an increasing rate, as the percentage of undersize increased.

When river anthracite is burned in a front-arch furnace the obtainable efficiencies are low due to the high "carry over" into the ashpit and to fly ash. The ignition is sluggish because of high moisture content, and as a result the rates at which the fuel may be burned per

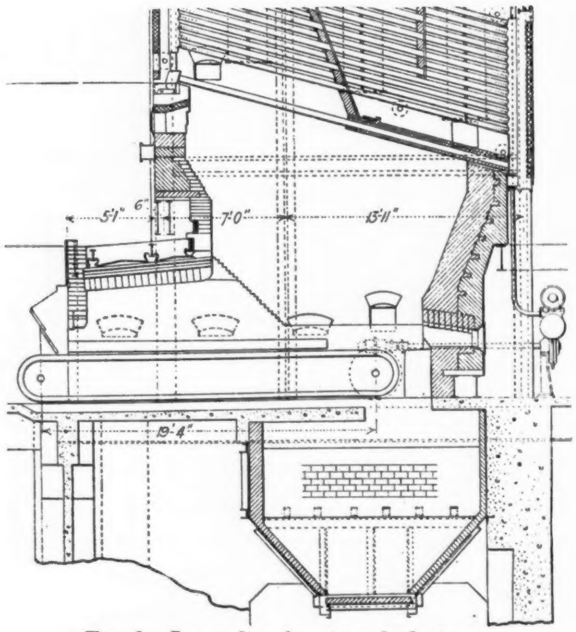


Fig. 1—An earlier front-arch design

square foot of grate surface are relatively low. In an attempt to overcome some of these inherent difficulties a multiple-arch furnace was designed and installed. The results exceeded expectation. Ignition was stable even at grate speeds that would cause ignition failure with No. 3 buckwheat, in a front-arch furnace. The CO_2 leaving the furnace was uniformly high and stratification of the gases was eliminated. The carbon loss in the ash-pit and also the fly ash was reduced very noticeably. The principal objection to this particular type of furnace was the large amount of refractory surface that would require maintenance.

As a direct result of the experiments on the multiple-arch furnace for river anthracite, the rear-arch furnace was finally evolved. Results, at first, however, failed to meet expectations. It was not until a new technique of operation was developed that the full possibilities of this design were realized. As will be seen in Fig. 2, the furnace consists essentially of a front curtain wall, commonly called the ignition arch, and a long low rear arch, extending from the bridgewall forward and covering sixty to seventy five per cent of the rear end of the stoker. Between the ignition arch and the rear arch is a relatively narrow "throat" which has an increasing area as it approaches the boiler surface. The height of the rear arch above the grate, the length of the rear arch and the width of the throat are all governed by the fuel to be burned as well as the rating.

The relatively large amount of high temperature refractory surface in this type of furnace, assures prompt ignition of the incoming fuel. The penetration of ignition, down through the fuel bed, is accelerated further because the air pressure, in the first stoker compartment is kept very low and is gradually stepped up toward the rear compartments. Furthermore, the gases coming forward under the rear arch carry a large quantity of fully ignited "fines" which fall on the incoming fuel bed and serve to speed up ignition still further. Therefore, with this design absolute stability of ignition is assured though grate speeds may be as high as 100 ft per hr.

The rear-arch type of furnace practically eliminates stratification of the products of combustion, by its mixing action. This is accomplished in the following manner. At the front of the furnace there is a relatively large quantity of rich gas distilled from the incoming green fuel at low velocity. This gas is deficient in air because of the method of operation. At the rear end of the furnace we have a large volume of lean gas. Due to the restricted volume under the arch, this lean gas moves forward at a relatively high velocity. Considerable turbulence is created in the narrow throat of the furnace where the low and high velocity streams of gas meet. They mix thoroughly and burn completely in the combustion chamber just above the throat.

The rear-arch furnace has proven itself in many installations. Where No. 3 buckwheat is burned, it is possible to obtain from two to four per cent higher efficiency than with the front-arch furnace. Combustion rates as high as 55 lb per sq ft per hr are not difficult to maintain. Where No. 4 buckwheat or river anthracite are burned, this rear-arch furnace is the only real insurance against ignition failure and extremely low efficiency. The combustion rates with these coals should rarely exceed 35 lb per sq ft per hr if reasonable efficiencies are desired. The rapid falling off in efficiency above this rate is due to the increased carry over in the fly ash.

The test results shown in Table I will serve as an indication of the relative performance of a boiler unit with front-arch or rear-arch furnace design. It will immediately be seen that the boiler exit gas temperature is lower in the case of the rear-arch furnace units, even though the base, or saturated steam temperature, is higher. The reason for this is that a more uniform gas mixture, in which the combustion is completed in the furnace, is passing over the boiler heating surface. At comparable combustion rates the efficiency is higher in the rear-arch units, even though the percentage of undersize in the fuel is very high. The true comparable efficiency of these furnaces is therefore higher than shown by these tests, as the basis of comparison should be coals of similar "undersize" content.

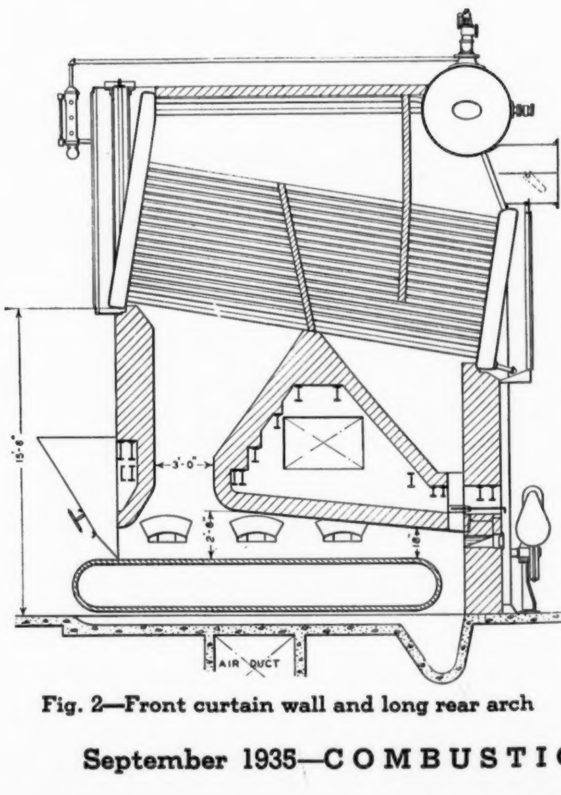


Fig. 2—Front curtain wall and long rear arch

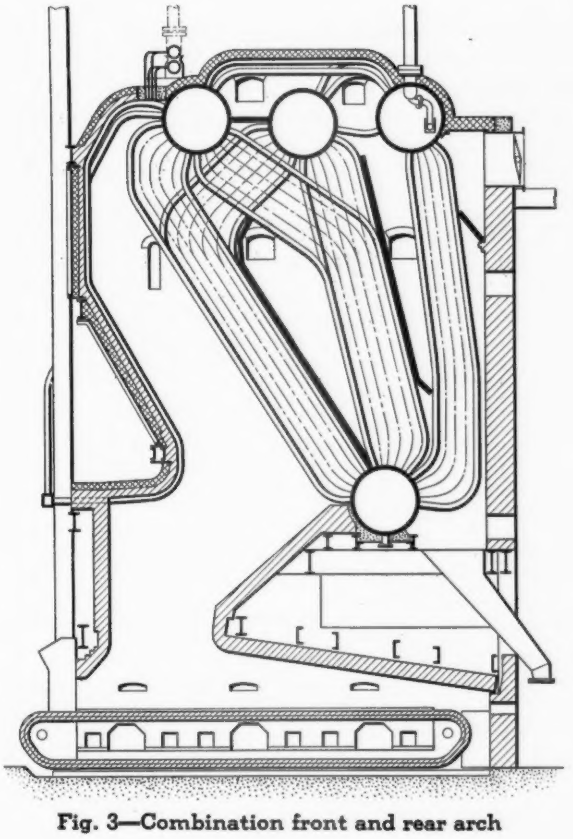


Fig. 3—Combination front and rear arch

In many installations it is not possible, because of space limitations, boiler setting height, etc., to provide a full rear-arch furnace. It may therefore be necessary to provide a combination-arch furnace similar to the one shown in Fig. 3. The results that it is possible to secure with this design, approach those obtainable in the full rear-arch type of furnace.

TABLE I

1.	Type of boiler	Horizontal water tube			
2.	Type of stoker	Forced-draft chain grate			
3.	Ratio of water-heating to grate surface	42.75:1	39.8:1	37:1	37:1
4.	Type of furnace	Front arch		Rear arch	
5.	Steam pressure, lb.	184.7	102.8	284.6	285.6
6.	Feedwater entering boiler, deg F	65.4	59.9	197	190
7.	Escaping gas, deg F	518	560	490	505
8.	Steam temperature, deg F			602	605
9.	Kind of fuel	No. 3 Buckwheat			
10.	Moisture in fuel, %	9.38	10.83	10.44	9.83
11.	Ash in fuel, %	15.96	14.49	16.97	16.04
12.	Btu per lb dry	12213	12534	11265	11675
13.	Percent undersize in fuel, %	.....	16.10	40.4	37.3
14.	Combined eff. furn. & boiler, %	72.3	72.64	76.6	74.00
15.	Dry coal per sq ft grate surf, per hr lb	27	29.05	25.4	33.3
16.	Per cent rating developed	167	207	177	232

A further advantage has been gained by the use of the rear-arch furnace in that it is possible to apply water cooling over the refractory surface. This has the advantage of reducing maintenance to a very low figure, and at the same time increasing the periods between outages occasioned by the necessity of repairing refractories. The installation illustrated in Fig. 4 is of the water-cooled design. It has operated continually for periods of over a year with only one or two days out of service to permit routine inspection.

Burning Coke Breeze

The burning of coke breeze, like anthracite, is practically limited to the forced-draft traveling grate stoker. Prior to 1916 this fuel was considered an undesirable "fill" around the steel mills. Today, many thousands of installed boiler horsepower are equipped with forced draft traveling grates on which coke breeze is burned.

Coke breeze, depending on the process from which it results, has a volatile matter content varying from 1 to 7 per cent. By far the larger quantity being burned lies in the range of 1 to 2 per cent volatile. Because of this and also because of its spongy-like structure, it is most difficult to ignite. Its abrasive character soon wears out screens, crushers and other equipment. The result is that the sizing of the fuel reaching the stokers is anything but uniform. Frequently segregation takes place in the bunkers and the stokers then receive a spotty mixture which burns out only partially. High carbon in ash and low CO_2, resulting from this condition, indicate an extremely poor efficiency. This can be corrected by installing downspouts to the stoker hoppers which uniformly distribute the fuel and minimize segregation.

An important factor in the burning of coke breeze, which should not be overlooked, is its sizing. Generally specifications call for all the breeze to pass through a $^3/_4$-in. round hole screen. This is not sufficient as there should be some dust present to aid in speeding ignition. This dust content should not be less than 20 per cent. If it exceeds 30 per cent increased carryover losses will result in lowered efficiency.

Since coke breeze is a low volatile fuel, its action in the furnace is similar to anthracite. Similar provisions in design must be made to insure prompt ignition and uniform mixing of the products of combustion. Fuel bed thickness is somewhat greater but the distribution of air under the grate is similar to that with anthracite.

The majority of installations, to date, have been of the front-arch design. In some cases, however, a short rear arch has been used. This arch extends forward from the bridgewall and covers about one foot of the rear end of the stoker. With this design it is possible to maintain uniformly high CO_2, provided over-fire air is properly

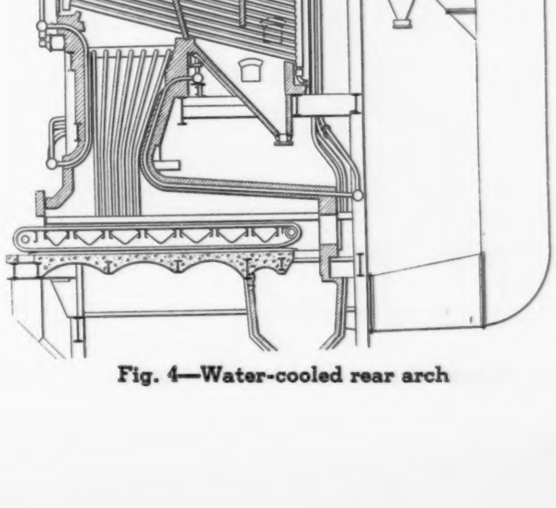


Fig. 4—Water-cooled rear arch

applied. This short arch also serves to prevent an excessive amount of fines from being carried over.

In some of the more recent installations the rear-arch type of furnace has been used. At first these arches were proportioned and arranged the same as for anthracite. This design resulted in high refractory maintenance because of the excessive furnace temperatures developed. By raising the rear arch, thereby lowering the gas velocity, this maintenance has been reduced to a reasonable figure. The improved results, as to stability of ignition and increased efficiency, easily offset the slight increase in cost due to the improved design.

The test results shown in Table II indicate the relative performance of boiler units fired with coke breeze, having the front- and rear-arch furnace design. Here again we see a decided improvement in efficiency due to furnace design.

TABLE II

1.	Type of boiler	Horizontal water-tube	
2.	Type of stoker	Forced-draft traveling grate	
3.	Ratio of water-heating to grate surface	43.9:1	39.6:1
4.	Type of furnace	Front arch	Rear arch
5.	Steam pressure in boiler, lb	185	104
6.	Feedwater entering boiler, deg F	187	178
7.	Escaping gas, deg F	545	565
8.	Steam temperature, deg F	442	395
9.	Kind of fuel	Coke breeze	
10.	Moisture in fuel, %	12.21	10.38
11.	Ash in fuel, %	16.80	11.04
12.	Btu per lb dry	11750	12620
13.	Per cent undersize in fuel	......	......
14.	Combined eff. furnace & boiler, %	71.32	77.3
15.	Dry coal per sq ft grate surf. per hr lb	35.3	21.6
16.	Per cent rating developed	20.1	159

Burning Semi-Anthracite

This fuel is classified by its volatile content which may range from 9 to 13 per cent. It has many of the true anthracite characteristics. It is relatively difficult to ignite and burns best when the fuel bed is left undisturbed. It is an ideal fuel for a forced-draft traveling grate stoker. Because of the small amount of this fuel available in the market, there are only a few installations in which it has been used.

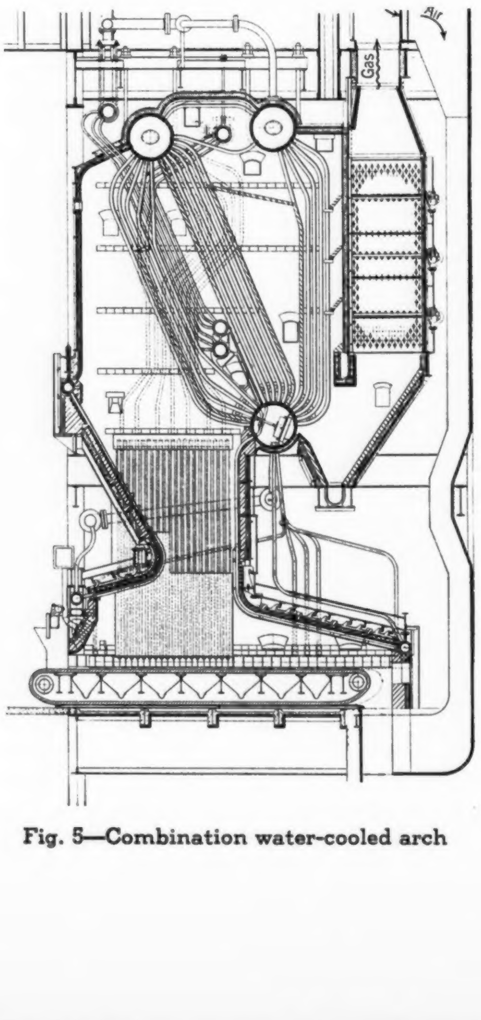


Fig. 5—Combination water-cooled arch

The same principles of furnace design as applied to anthracite may be applied to semi-anthracite and the results obtained will be comparable. The performance shown in Table III for a front-arch type of furnace parallels that in Table I.

TABLE III

1.	Type of boiler	Horizontal water-tube
2.	Type of stoker	Forced-draft traveling grate
3.	Ratio of water-heating to grate surface	42.4:1
4.	Type of furnace	Front arch
5.	Steam pressure in boiler, lb	195
6.	Feedwater entering boiler, deg F	196
7.	Escaping gas, deg F	527
8.	Steam temperature, deg F	......
9.	Kind of fuel	Semi-anthracite
10.	Moisture in fuel, %	11.47
11.	Ash in fuel, %	18.37
12.	Btu per lb dry	12207
13.	Undersize in fuel, %	......
14.	Combined eff. furnace & boiler, %	73.14
15.	Dry coal per sq ft grate per hr lb	32.2
16.	Per cent rating developed	203

Burning Bituminous Coal

Our greatest available supply of coal lies in the bituminous classification. Some of these coals are "free burning" and others coking or caking. Generally speaking, the sulphur and ash contents are high. The fusion temperature of the ash is frequently as low as 1900 F and clinkering occurs at the slightest provocation. Because of these characteristics, the forced-draft chain grate is ideally adapted when the "free burning" varieties are used.

Various forms of grate surface have been tried out. Because of the low fusion temperature and the slagging action of ash in some of the coals, some types of grate surface are heated more than others. The best surface has proved to be the link type with an air space of eight to twelve per cent. Because of the larger unit mass of metal in the link type it is better able to conduct the heat away from the fire side of the surface quickly. The average temperature of the metal is therefore lower and less subjected to burning. With the increasing use of preheated air, it is even more necessary that the stoker grate surface stand up with reduced cooling effect. Another requirement, which the link type fulfills, is that the grate surface must be self-cleaning. The shearing action of the links, as they pass over the rear sprockets, serves to remove any slag which may otherwise adhere and in time block the air opening of the grate.

Because of the high volatile content and long flaming character of these coals, larger furnace volumes are required than when burning anthracite and coke breeze. However, the higher volatile content assures prompt and rapid ignition and it is therefore possible to increase the height and reduce the length of the arch. Until recently the practical limit of rear arches consisted of water backs supporting bridgewall overhangs. With furnaces of this design it soon became evident that serious stratification occurred. Repeated tests demonstrated that the gases rising from the front end of the fuel bed were rich in CO and lean in CO_2. Many experiments were conducted to determine the correct method of undergrate air distribution to overcome this condition. Finally, the application of over-fire air proved to be the only real solution. In order to secure absolute control,

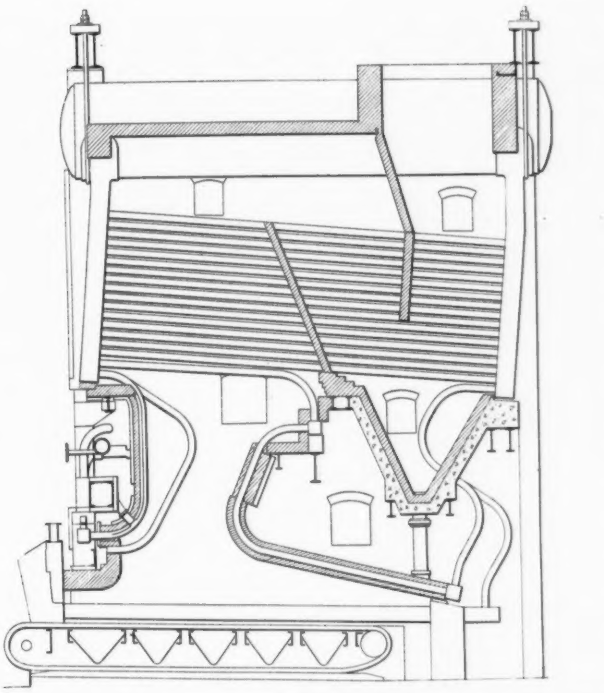


Fig. 6—A successful water-cooled rear arch design for high combustion rates

it was necessary to provide a small independent fan for supplying this air. The application of this air also served to correct the tendency of installations of this type to smoke.

A number of furnaces of the combination-arch design have been installed and the results have been uniformly excellent. In practically all of these installations the rear arch is considerably longer than the front arch. The air distribution is similar to that used in burning anthracite in the full rear-arch furnace. In a number of instances, the two arches are water cooled and additional cooling surface is also provided to cover a large portion of the side walls. Fig. 5 illustrates this design fully.

Several installations have also been made using the rear-arch type of furnace. In one of these a complete refractory-lined furnace was used. The arches were proportioned and arranged the same as for coke breeze. To date, after three and one-half years of continuous operation at varying loads, there have been no expenditures for refractory maintenance. In another installation a completely water-cooled rear arch has been installed. Predictions were made that ignition failure and excessive smoke would result. This particular installation, illustrated in Fig. 6, has now been in operation for several years. It has burned coal at very high combustion rates. There have been no violations of local smoke ordinances and no expenditures for furnace maintenance.

A series of test results, Table IV, show the actual results obtainable on the front arch and combination-arch types of furnace. The coals on these tests are from widely separated localities but their burning characteristics are similar.

In all of these tabulated tests the furnaces were operated without the use of over-fire air. To demonstrate the effectiveness when over-fire air is properly applied, the following results were obtained on a combination-arch type of furnace. The essential data are as follows: Escaping gas temperature 608 F; moisture in coal 16.56 per cent; ash in coal 15.88 per cent; Btu per pound dry 11610; combined efficiency of furnace and boiler 78.18 per cent; dry coal per square foot of grate per hour 38; per cent rating developed 224. The efficiency increase was due to the use of over-fire air.

Burning Sub-Bituminous and Lignite

Sub-bituminous coals are commonly known as black lignites. They differ from lignites in color and in the absence of the distinctly woody texture.

Lignites or brown coals are new coals. They are coals in the process of transformation from peat to sub-bituminous. The proportion of carbon is comparatively low, while the oxygen and inherent moisture are much higher than in true coals. The property of coking is usually absent and the ash content is often high. Their appearance is often claylike or woody.

Both the sub-bituminous coals and lignite have a decided tendency toward slacking, disintegrating and yielding their moisture on exposure to the air. This limits their use largely to localities where they are mined.

The tendency of these fuels to disintegrate is greatly accelerated when subjected to temperatures existing in boiler furnaces. Because of this action, drifting of the fuel bed is a common occurrence. When burned on underfeed stokers the entire fuel bed, at time of cleaning, may avalanche into the ash pit. The reason for this is that there is no tendency for the fuel bed to mat.

These fuels burn best when left undisturbed. The forced-draft traveling grate is therefore best adapted in installations where they are to be burned. Since the disintegrating quality causes these coals to break down

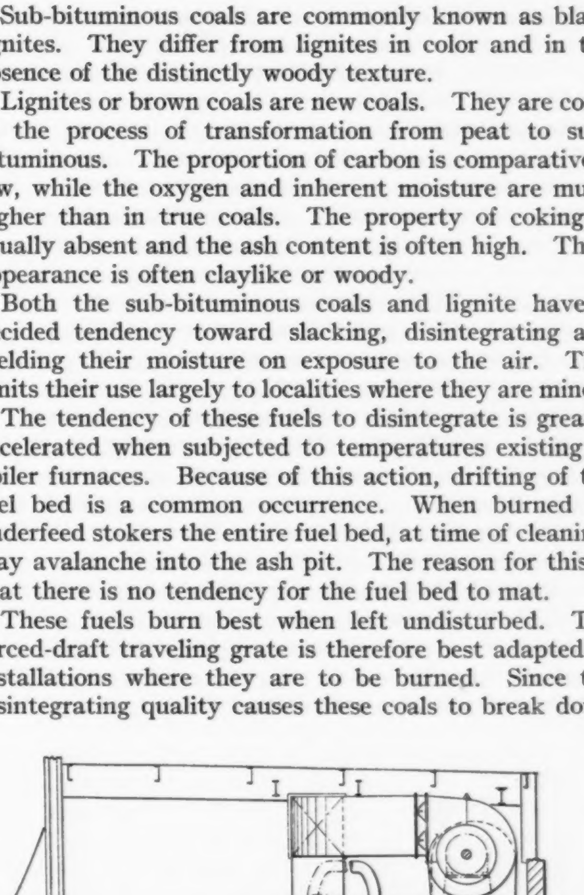


Fig. 7—Furnace designed for burning Texas lignite

TABLE IV

1.	Type of boiler	Horizontal water-tube					
2.	Type of stoker	Forced-draft chain grate					
3.	Ratio of water-heating to grate surface	45.4:1	45.4:1	45.4:1	42.1:1	42.1:1	42.1:1
4.	Type of furnace		Front arch			Combination arch	
5.	Steam pressure in boiler, lb	192.3	192.5	188	259.2	261.1	263.3
6.	Feedwater entering boiler, deg F	207	207	207	234	218	232.9
7.	Escaping gas, deg F	636	639	614	551	541	621
8.	Steam temperature, deg F	511	517	494	632.7	585.9	651.1
9.	Kind of fuel				Bituminous		
10.	Moisture in fuel, %	12.8	3.0	2.0	11.38	17.23	17.85
11.	Ash in fuel, %	13.48	15.46	19.22	15.97	15.32	15.24
12.	Btu per lb dry	12,164	12,618	12,167	12,373	11,674	11,859
13.	Combined eff. furn. & boiler, %	74.1	70.0	74.4	73.86	77.84	74.68
14.	Dry coal per sq ft grate per hr lb	42.4	43.6	43.5	32.5	28.4	41.5
15.	Per cent rating developed	222	224	231	211	184	261

into fine particles, it is necessary to provide a real non-sifting grate surface. It should consist of small individual end overlapping elements. The free air space provided should be between seven and ten per cent. The air supply to the grate should be zoned so that accurate control of the air pressure and quantity may be maintained. Controllable over-fire air, through the ignition arch, should be provided.

As the inherent moisture content in lignite is high, between 20 and 28 per cent, ignition penetration is slow. The furnace design must therefore be such as to reflect the maximum amount of heat onto the incoming fuel. The front-arch type of furnace has been tried a number of times. Invariably ignition is slow, the fuel failing to light off until it has travelled several feet into the furnace. This condition results in poor efficiency, due to low CO_2 and high carbon loss in ashpit. Furthermore, a combustion rate of 25 lb per sq ft per hr is most difficult to maintain. As the heat value of this fuel is very low, the aforementioned condition would require extremely large grate surface to develop nominal boiler output.

Several years ago a rear-arch type of furnace was designed, and installed, in an attempt to improve operating results with lignite. At the same time, an air preheater was provided to supply heated air to the stoker grates. Operating conditions were immediately improved. Ignition was prompt and penetrated the fuel bed quickly. Combustion rates of 55 to 65 lb per sq ft per hr were readily maintained. The CO_2 at the boiler outlet was maintained at between 15 and 16 per cent without difficulty. The combustible matter in the ashpit refuse was reduced to a point where it became an insignificant factor in the heat balance accounting. Efficiencies were comparable to those obtained with the best grades of coal.

A number of units, of similar design, have since been installed in other localities. The results, in every case, have been uniformly excellent. The unit illustrated in Fig. 7 has been in operation at the heating plant of the University of Texas for some time. Texas lignite is the only fuel burned in this plant. Careful tests to measure its performance, have been conducted and the results reported in detail.[1] Items from these tests have been extracted along with results from an installation burning Dakota lignite and one burning Saskatchewan lignite are shown in Table V. On two of these installations preheated air is used and is a most valuable aid in rapidly igniting the incoming fuel. Loads that vary from "live bank" to maximum capacity are easily carried with uniformly high efficiency.

[1] See COMBUSTION, July 1934.

Burning Coking Bituminous Coal

As previously stated, "free burning" bituminous coals are ideal ones for chain-grate operation. There has been a tendency, at times, to assume that coking bituminous coals, can also be burned on forced-draft chain grates, with high efficiency. This is not generally the case, as these coals have a tendency to mat over the grate surface. Soon fissures appear in the fuel bed and a large portion of the air for combustion finds its way into the furnace, through them. As a result, the fixed carbon is not completely burned out and manifests itself in the high carbon content of the ashpit refuse. Some of these coals, however, if carefully selected as to sizing and volatile matter content, may be so burned successfully and with high efficiency. The furnace best adapted to their use is of the high front-arch design, with a rear arch consisting of water backs supporting an overhanging bridgewall. Air over the fire, through the arch, is essential. The link-type of stoker should be used to minimize overheating of the grate, as the ash content of these coals is quite low. Combustion rates up to 40 lb per sq ft may be maintained without excessive ashpit losses. Low grate speeds, thick fuel beds burned out as quickly as possible, are essential. CO_2 may be readily maintained between 14.5 and 16 per cent provided some furnace water cooling is installed. With CO_2 at 14.5 per cent and a boiler exit gas temperature of approximately 500 F, an efficiency of 78 per cent may be obtained in daily operation. However, it should be remembered that the coal must be fitted to the installation. No predictions, as to performance, can be made from either proximate or ultimate analyses. Actual operating tests are the sole means of judging which coals may be used. Because of this, there should be considerable hesitancy on the part of any plant owner to install chain grates for burning coking varieties of bituminous coals.

TABLE V

1.	Type of boiler	Horizontal water-tube				Bent tube
2.	Type of stoker	Forced-draft traveling grate				
3.	Ratio of water-heating to grate surface	30.2:1	23.2:1	31.0:1	31.0:1	39.6:1
4.	Type of furnace	Rear arch				Rear arch
5.	Steam pressure in boiler, lb	207	147	217	207	103
6.	Av. feedwater entering boiler, deg F	164	105	174	186	185
7.	Escaping gas, deg F	365	338	490	535	578
8.	Steam temperature, deg F	519	488	624	636	405
9.	Kind of fuel		Texas lignite		N. D. lignite	Sask. lignite
10.	Moisture in fuel, %	35.12	33.5	33.2	32.8	36.81
11.	Ash in fuel, %	8.26	10.37	7.27	6.90	8.3
12.	Btu per lb dry	11,400	10,800	10,708	10,750	10,530
13.	Combined eff. furn., boiler and air heater, %	77.6	80.3	74.2	67.3	74.9*
14.	Coal per sq ft of grate per hr (as fired), lb	26.2	18.7	35	52	46.1
15.	Per cent rating developed, lb	125	141	182	250	176

* Unit not equipped with air preheater.

ILLINOIS COALS—Their Classification and Analyses

By P. B. PLACE

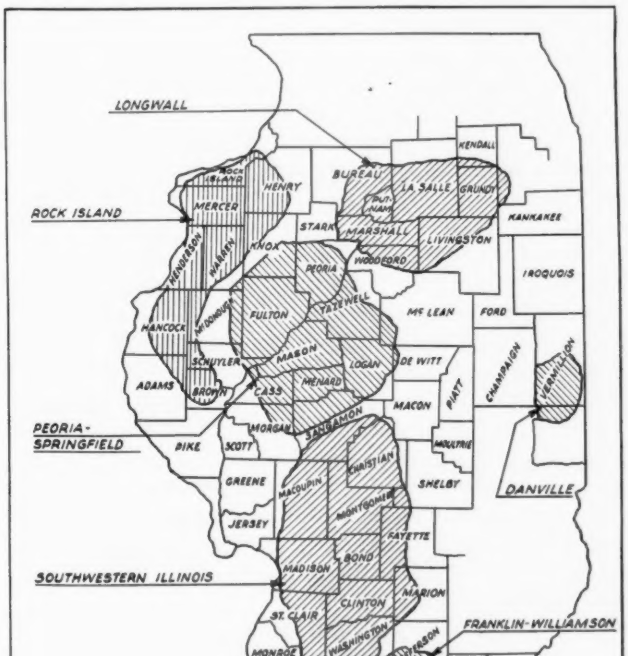
Combustion Engineering Company, Inc.

Illinois produces ten to twelve per cent of the bituminous coal mined in the United States. This coal is produced in eight districts within the state. The different seams are identified with the trade names and the characteristics of the coals are discussed, as was done in the previous articles of this series which have taken up Ohio, Kentucky and Virginia coals.

OVER 35,000 square miles of the state of Illinois is underlain with a coal reserve that is double that of Pennsylvania and estimated to be about two hundred billion tons. The Illinois coal fields, together with those of Indiana and Western Kentucky, constitute the Eastern Region of the Interior Coal Province.

Illinois contributes ten to twelve per cent of the bituminous coal mined in the United States and competes with Kentucky for third place in the order of production. Table I gives the relative production of several states during recent years. Within the state, Franklin county in southern Illinois leads with twenty to twenty-five per cent as shown in Table II which gives the relative production of the principal counties in recent years.

As in other states, the coal bearing area in Illinois is divided into mining districts which are named after established centers of mining activity. At present there are eight such districts, the location and extent of which are indicated on the map. The names of the districts, the counties included and the principal seams mined are listed in Table III.



Coal producing districts in Illinois

All of the Illinois coal seams are found in the Pennsylvania series of the Carboniferous Age. The series has been divided into three coal bearing formations named the Pottsville, Carbondale and McLeansboro (top) corresponding to the Pottsville, Alleghany and Conemaugh formations of the Eastern Fields. The Pottsville formation is the deepest and lies below the No. 2 seam. The only coal mined from this formation is the No. 1 and its production is so limited as to be of little importance. Similarly, the No. 7 seam is the only seam mined in the McLeansboro formation and it has a limited production as Danville coal in Vermillion county. All of the other seams of value are in the Carbondale formation which contributes ninety per cent or more of the state's production. Though several seams are found in these formations, those of commercial value are the Nos. 6, 5, 2, 7 and 1 in order of their importance. The No. 6 and No. 5 seams are also mined in Indiana where they are known by the same number and in western Kentucky where they are designated as No. 11 and No. 9, respectively.

The No. 6 seam is at present the most productive and is known by several trade names, some of which are given in Table III. The seam is six to ten feet thick and is characterized by a thin layer of shale that runs through the seam and which has to be separated during mining. This strip of shale gives the coal its name "Blue Band." In Franklin county this seam yields a low sulphur coal that is suitable for making coke and gas. The ash in the No. 6 occurs largely as partings that are separable by

TABLE I
RELATIVE PRODUCTION OF BITUMINOUS COAL
IN PRINCIPAL COAL PRODUCING STATES
1929 - 1932
PER CENT OF TOTAL BITUMINOUS PRODUCTION

State	1929	1930	1931	1932
West Virginia	25.9	26.0	26.5	27.7
Pennsylvania	26.8	26.6	25.6	24.1
Illinois	11.4	11.5	11.6	10.8
Kentucky	11.3	11.0	10.5	11.4
Ohio	4.4	4.8	5.4	4.5
Indiana	3.4	3.5	3.7	4.3
Alabama	3.4	3.3	3.1	2.5
Virginia	2.4	2.3	2.5	2.5
	89.0	89.0	88.9	87.8

TABLE II
RELATIVE PRODUCTION OF BITUMINOUS COAL
IN PRINCIPAL COUNTIES OF ILLINOIS
1929 - 1932
PER CENT OF TOTAL PRODUCTION OF STATE

County	1929	1930	1931	1932
Franklin	24.1	22.1	21.1	20.5
Perry	4.8	6.1	6.6	9.2
Saline	6.8	7.3	6.6	7.1
St. Clair	4.6	4.6	6.3	6.5
Macoupin	8.3	8.6	9.0	5.8
Williamson	8.6	7.5	4.8	5.6
Vermillion	5.0	5.3	5.6	5.6
Sangamon	7.1	6.9	7.5	5.5
Christian	5.8	6.6	6.5	5.3
Jackson	2.6	3.7	4.3	3.9
	77.7	78.7	78.3	75.0

TABLE III
MINING DISTRICTS IN ILLINOIS

District	Counties Included	Coal Seam Mined Number	Coal Seam Mined Name
Franklin-Williamson	Franklin, Williamson, Jefferson, Perry	6	Williamson Franklin Herrin Carterville
Southwestern Illinois Central Illinois	Christian, Macoupin, Perry, Sangamon, St. Clair, Bond, Clinton, Madison, Marion, Montgomery, Moultrie, Randolph, Shelby, Washington	6	Blue Band Belleville Standard Montgomery Staunton Grape Creek
Danville	Vermillion, Edgar	6	Grape Creek
Peoria-Springfield Fulton-Peoria	Fulton, Peoria, Sangamon, Cass, Dewitt, Knox, Logan, Macon, Mason, Menard, McLean, Schuyler, Tazewell, Woodford, McDonough	5	Peoria Springfield No. Illinois Rushville
Saline Saline-Gallatin	Saline, Gallatin	5	Harrisburg Ledford Eldorado
Longwall Wilmington LaSalle Northern	Bureau, Grundy, LaSalle, Marshall, Putnam, Will, Woodford	2	Third Vein La Salle Wilmington
Jackson Big Muddy	Jackson	2	Big Muddy Jackson Murphysboro
Rock Island	Mercer, Rock Island, Brown, Cass, Fulton, Green, Hancock, Henry, Jersey, Knox, Morgan, Scott	1	Rock Island Seville

Note: The more important producing counties are underlined.

mechanical methods and the lump sizes of the seam are cleaner than the slack. This coal, from Franklin and Williamson counties, together with the No. 5 seam from Saline county are the typical southern Illinois coals.

The No. 5 seam is mined in both the northern and southern part of the state. In the Peoria district, it is a typical northern Illinois coal and of poorer quality than it is in the Saline district where it resembles the No. 6 seam. The coal is hard and its ash is high. The latter is more dispersed than in the No. 6 seam and the coal has a less laminated appearance and is harder to clean.

The No. 2 seam was formerly the principal seam mined in the state and the Big Muddy coal (now practically mined out) from Jackson county was considered the best in the state. The No. 2 is mined in the Longwall district where it resembles the No. 5 seam of the Peoria district.

In general, Illinois coals are classed as free burning bituminous. They are high in moisture, ash, sulphur and volatile matter: are harder than eastern high-volatile coals and mine out in large blocks or slabs. They have a characteristic laminated appearance due to a banded structure of alternate bright and dull coal. Much of the ash occurs as partings deposited on the cleavage faces and since these partings crumble and are separated easily, the lump, block and larger sizes of Illinois coal are cleaner than the slack. Two characteristic ash partings in Illinois coals are calcium sulphate and calcium carbonate (calcite). The first occurs as thin flat white deposits and the second as translucent scales that may be removed with a knife or finger nail. The ash is classed as low fusion with a melting point generally between 1900 and 2100 F.

Illinois coals are high in volatile matter and burn with a long luminous flame. They are best burned on a chain grate stoker or in pulverized form. Though classed as free burning, some of the lower sulphur coals of southern Illinois will form fairly strong coke and are suitable for coke and gas making.

Analyses of Illinois coals are given in Tables IV, V, VI and VII. As in previous publications, the analytical values are given on a "moisture-and-ash-free" basis with a range of moisture and ash values on an "as-received" basis. The latter are subject to variations due to mining methods, degree of cleaning and weathering but the analytical values for the coal substance are fairly constant for coals mined from the same seam in the same district. Illinois coals have considerable variation in sulphur content and analyses are often reported on a "moisture-ash-and-sulphur-free" basis to establish the basic analytical values. The object of the present series of articles, however, is to furnish a guide for setting up and checking analyses in the absence of a coal chemist's assistance. The moisture and ash for a given coal can be determined with reasonable accuracy in any small plant laboratory and the other values may then be calculated from the "moisture-and-ash-free" values given in the tables.

Table IV gives typical individual analyses of the two principal seams in various counties. These analyses are not selected and show the normal variation in coal from the same seam and county. Table V gives average proximate and ultimate analyses of coals from the principal counties and districts. To convert the "moisture-and-ash-free" values into "as-received" values for any given moisture and ash, multiply by the ratio (100 − (per cent moisture + per cent ash)/100). Table VI gives average proximate analyses on an "as-received"

TABLE IV
TYPICAL INDIVIDUAL ANALYSES OF COAL

COUNTY AND SEAM	VOLATILE MATTER	FIXED CARBON	SULPHUR	HYDROGEN	CARBON	NITROGEN	OXYGEN	BTU/LB	MOISTURE	ASH
	MOISTURE-AND-ASH-FREE								AS-RECEIVED	
NO. 6 SEAM - FRANKLIN COUNTY	39.0	61.0	1.9	5.2	81.1	1.8	9.9	14450	9	9
	41.5	58.5	1.2	5.2	81.2	1.7	10.7	14475	8	10
	40.5	59.8	1.8	5.4	80.7	1.7	10.3	14555	9	11
	37.3	62.7	0.6	4.7	80.5	1.8	12.3	14225	8	10
	41.0	59.0	1.1	5.4	81.6	1.8	10.0	14470	9	8
AVERAGE	39.8	60.2	1.3	5.2	81.0	1.8	10.7	14435	8-9	8-11
NO. 6 SEAM - WILLIAMSON COUNTY	39.1	60.9	3.1	5.2	80.8	1.2	9.7	14395	12	11
	39.0	61.0	3.1	5.3	80.7	1.4	9.5	14580	15	10
	38.7	61.3	2.0	5.3	81.4	1.6	9.8	14615	8	7
	39.2	60.8	2.5	5.3	81.3	1.7	9.2	14575	7	11
	36.7	63.3	1.4	5.2	82.1	1.8	9.5	14590	8	11
AVERAGE	38.5	61.5	2.4	5.3	81.3	1.5	9.5	14550	7-15	7-11
NO. 6 SEAM - MACOUPIN COUNTY	47.1	52.9	5.3	5.6	77.5	1.3	10.3	14270	13	10
	47.7	52.3	5.2	5.6	77.6	1.3	10.3	14310	13	10
	43.7	56.3	5.4	5.3	77.1	1.4	10.9	14030	14	13
	48.6	51.4	5.1	5.4	77.6	1.5	10.4	13980	13	9
	49.6	50.4	6.8	5.4	76.6	1.3	9.9	13930	12	13
AVERAGE	47.3	52.7	5.4	5.5	77.3	1.4	10.4	14105	12-14	9-13
NO. 5 SEAM - SALINE COUNTY	40.0	60.0	2.8	5.3	80.4	1.7	9.7	14820	7	8
	39.3	60.7	3.5	5.2	79.8	1.6	9.9	14690	9	11
	37.3	62.7	1.9	5.3	82.6	1.6	8.6	14755	6	8
	40.2	59.8	3.4	5.3	80.2	1.5	9.6	14745	5	8
	40.3	59.7	3.0	5.4	81.9	1.8	7.9	14610	6	8
AVERAGE	39.4	60.6	2.9	5.3	81.0	1.6	9.2	14725	5-9	8-11
NO. 5 SEAM - PEORIA, SANGAMON, FULTON, LOGAN, TAZEWELL COUNTIES	47.2	52.8	4.2	5.6	79.5	1.5	9.2	14350	14	11
	48.5	51.5	5.4	5.5	77.6	1.5	10.0	14050	13	10
	48.0	52.0	4.4	5.4	79.3	1.5	9.6	14190	15	11
	48.6	51.4	4.6	5.4	79.0	1.5	9.5	14230	14	12
	47.4	52.6	4.3	5.5	79.0	1.5	9.3	14240	15	9
AVERAGE	47.9	52.1	4.6	5.5	79.0	1.5	9.4	14210	13-15	9-12

TABLE V
AVERAGE ANALYSES OF ILLINOIS COALS

DISTRICT AND COUNTY	VOLATILE MATTER	FIXED CARBON	SULPHUR	HYDROGEN	CARBON	NITROGEN	OXYGEN	BTU/LB	MOISTURE	ASH
	MOISTURE-AND-ASH-FREE								AS-RECEIVED	
FRANKLIN-WILLIAMSON - NO. 6 COAL										
FRANKLIN	39.3	60.7	1.3	5.2	81.6	1.7	10.2	14480	7-10	7-12
WILLIAMSON	39.5	60.5	2.6	5.3	81.1	1.6	9.4	14500	8-15	7-12
JEFFERSON	41.8	58.2	1.6	5.4	81.2	1.8	10.0	14460	7-11	6-10
AVERAGE	40.2	59.8	1.8	5.3	81.3	1.7	9.9	14480	7-15	6-12
SOUTHWESTERN ILLINOIS - NO. 6 COAL										
ST. CLAIR	48.1	51.9	5.4	5.5	77.7	1.3	10.1	14145	9-15	10-16
MACOUPIN	47.1	52.9	5.3	5.5	77.2	1.4	10.6	14100	12-16	8-16
SANGAMON	47.3	52.7	5.5	5.4	77.5	1.5	10.1	14125	12-16	11-14
CHRISTIAN	47.9	52.1	5.1	5.6	77.5	1.5	10.4	14090	10-12	9-11
MADISON	47.9	52.1	5.5	5.5	77.3	1.3	10.4	14080	10-18	8-18
MONTGOMERY	47.4	52.7	5.6	5.4	77.4	1.5	10.1	13980	10-12	9-11
PERRY	45.7	54.3	4.2	5.2	78.4	1.5	10.6	14060	10-17	7-11
MARION	45.9	54.1	4.9	5.5	78.3	1.5	9.8	14270	9-12	8-14
BOND	45.5	54.5	4.4	5.3	78.8	1.4	10.1	13960	10-12	9-11
AVERAGE	47.0	53.0	5.1	5.4	77.8	1.4	10.3	14090	9-18	7-18
DANVILLE - NO. 6 COAL										
VERMILLION	46.5	53.5	2.8	5.4	80.1	1.6	10.1	14320	10-17	7-11
PEORIA-SPRINGFIELD - NO. 5 COAL										
SANGAMON	48.3	51.7	5.3	5.5	78.6	1.5	9.1	14140	11-16	10-14
FULTON	48.0	52.0	4.4	5.4	79.3	1.5	9.6	14190	12-16	7-11
PEORIA	46.2	53.8	4.2	5.6	79.5	1.5	9.2	14340	10-13	8-11
MACON	47.7	52.3	4.5	5.5	77.9	1.4	10.8	14100	12-14	9-11
LOGAN	46.8	53.2	4.5	5.4	79.0	1.4	9.7	14230	12-16	10-12
AVERAGE	47.4	52.6	4.6	5.5	78.9	1.5	9.5	14200	10-16	7-14
SALINE-GALLATIN - NO. 5 COAL										
SALINE	39.8	60.2	3.0	5.4	81.3	1.7	8.6	14680	4-10	7-12
LONGWALL - NO. 2 COAL										
BUREAU	50.3	49.7	3.8	5.4	78.5	1.4	10.9	14250	14-18	5-10
LASALLE	49.8	50.2	4.4	5.7	78.0	1.3	10.6	14340	11-15	6-11
AVERAGE	50.0	50.0	4.1	5.5	78.3	1.4	10.7	14295	11-18	5-11

TABLE VI
AVERAGE PROXIMATE ANALYSES OF ILLINOIS COALS
(AS-RECEIVED BASIS)

COUNTY	SEAM NO.	MOISTURE	ASH	VOLATILE MATTER	FIXED CARBON	SULPHUR	BTU/LB
FRANKLIN	6	9.1	8.8	33.5	48.6	1.4	11815
WILLIAMSON	6	8.1	9.3	33.5	49.1	2.2	11550
PERRY	6	10.1	10.1	34.4	45.4	2.1	11310
	AVERAGE	9.1	9.4	33.8	47.7	1.9	11560
ST. CLAIR	6	11.2	11.0	38.0	39.8	3.7	10920
MACOUPIN	6	13.4	9.9	37.3	39.4	4.0	10750
SANGAMON	6	14.1	10.0	36.8	39.1	4.2	10640
CHRISTIAN	6	12.5	10.3	37.1	40.1	3.9	10865
MADISON	6	13.1	12.5	35.6	43.8	3.7	10655
MONTGOMERY	6	13.5	10.8	35.0	40.7	3.9	10660
PERRY	6	9.9	11.0	36.6	42.5	3.5	11090
MARION	6	10.4	11.2	36.5	41.9	4.0	11155
BOND	6	12.0	10.3	35.1	42.6	3.4	10805
CLINTON	6	12.4	10.3	34.8	42.5	3.5	10870
MOULTRIE	6	7.0	11.5	39.2	42.3	4.0	11880
RANDOLPH	6	9.7	11.4	36.9	42.0	3.9	11045
WASHINGTON	6	10.3	11.7	38.4	39.6	4.1	10960
	AVERAGE	11.5	10.9	36.7	40.8	3.8	10945
VERMILLION	6	14.8	9.4	35.7	40.4	2.3	10855
SANGAMON	5	13.9	10.8	36.4	38.9	4.0	10650
FULTON	5	15.7	11.2	35.5	37.6	3.2	10470
PEORIA	5	14.2	12.0	34.2	39.6	3.3	10655
MACON	5	13.7	9.8	36.3	40.2	3.5	10775
LOGAN	5	14.2	11.3	35.1	39.4	3.3	10595
TAZEWELL	5	15.1	9.5	36.0	39.4	3.2	10735
MENARD	5	17.3	8.2	36.9	38.6	3.4	10500
MCLEAN	5	13.3	12.5	38.0	36.2	3.7	10580
	AVERAGE	14.7	10.7	35.9	38.7	3.4	10615
SALINE	5	6.1	8.5	34.4	51.0	2.8	12520
GALLATINE	5	4.6	10.4	35.1	49.9	3.4	12545
	AVERAGE	5.3	9.5	34.8	50.4	3.1	12535
BUREAU	2	16.3	7.4	38.3	38.0	2.9	10885
LASALLE	2	14.6	8.2	38.2	39.0	3.3	11020
GRUNDY	2	17.2	5.3	38.5	39.0	2.3	11115
MARSHALL	2	15.0	7.2	39.1	38.7	2.8	11315
		15.8	7.0	38.5	38.7	2.8	11085
JACKSON	2	8.5	7.1	34.4	50.0	2.3	12370

basis for coals from the principal counties and districts, the moisture and ash values being typical of mine samples.

The Illinois coal field has not been greatly disturbed by upheaval of its rock formation and consequently the coal seams do not show the local results of pressure and carbonization that are common in the eastern fields. In general, the quality of the Illinois seams increases from north to south and the coals are often classified as "northern Illinois" and "southern Illinois" without further identification of seam or county. In Table VII typical analyses of a northern and southern Illinois coal are given on an as-received, dry and moisture-and-ash-free basis. These values are averages for the districts and coals listed, approximately weighted on a production basis. When the exact source of the coal is not known, it may be often identified as a southern or northern coal by its sulphur content, volatile content and physical appearance.

TABLE VII
AVERAGE ANALYSIS FOR NORTHERN ILLINOIS COAL

		AS-RECEIVED	MOISTURE-FREE OR DRY	MOISTURE-AND ASH-FREE
DISTRICTS				
Southwestern Illinois,	M	12.0	-	-
Peoria-Springfield,	A	9.0	10.23	-
Longwall, Rock Island	Vol.	37.60	42.73	47.6
	F.C.	41.40	47.04	52.4
		100.00	100.00	100.0
Coals No. 6, 5, 2 and 1	S	3.79	4.31	4.8
	H	4.27	4.85	5.4
	C	61.78	70.20	78.2
	N	1.10	1.25	1.4
	O	8.06	9.16	10.2
		79.00	89.77	100.0
	BTU	11185	12710	14160

AVERAGE ANALYSIS FOR SOUTHERN ILLINOIS COAL

		AS-RECEIVED	MOISTURE-FREE OR DRY	MOISTURE-AND ASH-FREE
DISTRICTS				
Franklin-Williamson,	M	9.0	-	-
Danville, Saline, Jackson	A	8.0	8.79	-
	Vol.	33.86	37.21	40.8
	F.C.	49.14	54.00	59.2
		100.00	100.00	100.0
Coals No. 6, 5 and 2	S	1.91	2.10	2.3
	H	4.48	4.92	5.4
	C	67.40	74.07	81.2
	N	1.41	1.55	1.7
	O	7.80	8.57	9.4
		83.00	91.21	100.0
	BTU	12060	13250	14530

The analyses and description of Illinois coals are given in further detail in several publications of the Illinois Geological Survey and the United States Bureau of Mines. The following are recommended for reference:

Illinois Coal by A. Bement 1929
Bulletin No. 56 Illinois Geological Survey
Analyses of Illinois Coals by G. W. Hawley 1923
Bulletin No. 27 Illinois Geological Survey

George E. Seabury, superintendent of the station engineering department of the Edison Electric Illuminating Company of Boston has retired. Prior to his twenty-three years service with that company he had been in the construction and steam turbine departments of the General Electric Company.

Sponsored by Mayor La Guardia of New York the Board of Estimate has approved a bill calling for a municipal power plant referendum at the November election. The project if carried will cost approximately $45,000,000.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Embrittlement Tests for Turbine Steels

With a view to determining the resistance to embrittlement of several steels widely used for disks, studs and bolts in British turbine practice, which in service are subjected for long periods to temperatures of about 450 C, a series of tests were recently conducted in an electric furnace approximating these conditions. The results are discussed by D. A. N. Sandifer in the July 26 issue of *Engineering*.

The steels selected are known by the trade names of Durehete, Tormanc Major, Tormanc and Tormol and have the following composition:

	Durehete	Tormanc Major	Tormanc	Tormol
C%	0.5	0.31	0.33	0.32
Mn%	0.6	1.3	1.34	0.56
Si%	0.237	0.165	0.171	0.239
S%	0.035	0.033	0.034	0.036
P%	0.037	0.035	0.034	0.031
Ni%	0.08	...	...	2.64
Cr%	1.16	...	...	0.71
Mo%	0.59	0.2	...	0.49

The obvious test for brittleness was the Izod impact test and the variables were the period of soaking at the above temperature and the temperature at which the steels were tempered. Two groups of tests were carried out the first on all four steels oil-tempered at 575 C and the second group on all four steels tempered at 600 C. The steels, in the order given, were oil hardened at 850 C, 840 C, 830 C and 830 C, respectively.

The steels Durehete, Tormol and Tormanc Major all contain molybdenum and all were unaffected in their Izod values for the tempering temperatures considered, whereas Tormanc which contains no molybdenum, suffers serious embrittlement for both the tempering temperatures. It has been suggested that the presence of manganese may tend to produce embrittlement especially if the amount is more than one per cent although a very small percentage of molybdenum will tend to counteract this. The results on Tormanc Major containing practically as much manganese as Tormanc with the addition of 0.2 per cent molybdenum, demonstrates this point.

Accumulations Rendered Low-Water Alarm Inoperative

Engineering of August 9th summarizes some reports of investigations by the British Board of Trade into boiler explosions and failures. One case is of particular interest as indicating that low-water alarms, while appliances of proved utility, may be a source of danger if relied upon to the exclusion of indications by the water gages. In this case a Stirling boiler, fitted with safety valves set to blow at 200 lb, had two gage glasses and a high-and-low water alarm of the balanced-float type. The boiler always showed a tendency to prime when worked hard and there was apparently difficulty at times in maintaining the proper water level. A tube suddenly ruptured and examination showed that other tubes were swollen or sagged, that the front drum had sagged $^5/_{16}$ in. and that a number of tube holes were distorted. This led to the conclusion that there had been over-heating due to shortness of water although the feed and the gage glasses were found in satisfactory condition. It was subsequently found that through foaming and priming deposits had collected on the high-water float to such an extent that it required over three pounds on the low-water float to effect a balance when the boiler was empty. Under these circumstances the low-water float was unable to fall with the water level and for all practical purposes the alarm was inoperative.

Water Softening on the "Queen Mary"

The 73,000-ton Cunard-White Star liner "Queen Mary" which is now nearing completion will have its boiler feedwater conditioned by a combined lime and base exchange plant operating on the dual principle with quartz pressure filters. According to *Engineering and Boiler House Review* for August, this plant will have capacity to handle 300 tons of makeup water per hour. It will include two 4-ft diameter sand filters, which will be cleaned at intervals by means of a steam ejector, and two base exchange units operating with "Basex" material to give zero hardness with no alkalinity.

Employs Steam Compressor on Heating System

Zeitschrift des Vereines deutscher Ingeneuire for June 22, 1935, contains an interesting description of a steam compressor installation employed by the central steam heating system at Braunschweig, Germany, for maintaining the desired pressure in the heating mains at periods when the power demands on the bleeder turbines make it difficult to maintain the desired extraction pressure. Inasmuch as the electrical load on the turbines does not coincide with the demands on the heating system there were periods during the day when the greater part of the heating demand had to be met by live steam throttled to the distribution pressure. By installing the steam compressor the extraction steam and exhaust from the auxiliaries is boosted to the desired pressure and the supply of live steam is greatly reduced. It is pointed out that the

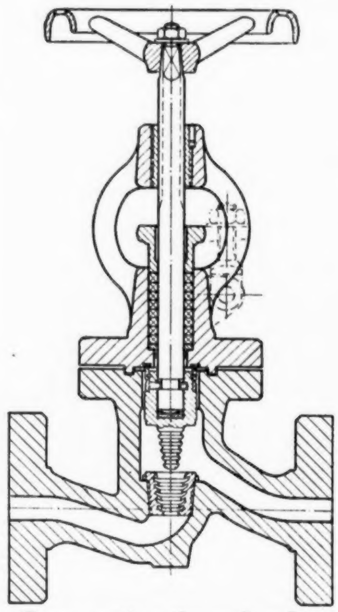
(*Continued on page 34*)

(*Continued from page 33*)

efficiency of the compressor is extremely high as all losses, except radiation are returned as useful heat as is also the exhaust from the turbine driving the compressor.

Labyrinth Valve Seat

Manufacturers of valves in Germany are still actively engaged in finding better solutions for making valves with closure means which form a positive seal. Valve seats which form the seal are subject to slow progessive wear by the cutting action of the flowing steam and this action is amplified by the presence of solid particles entrained by the steam, such as scale, silica, slime and the like. To overcome such objectionable cutting action one manufacturer has introduced a throttling valve as shown in the accompanying illustration, reproduced from the June issue of *Archiv fur Wärmewirtschaft und Dämpfkesselwesen.* Ahead of the valve seat there is provided a labyrinth path which reduces in steps the energy of the flowing steam and therewith its velocity, particularly at the first opening movement of the valve. The labyrinth corrugations are formed on special metal parts which are respectively mounted on the valve stem and in the valve body.



Cross section through valve

An Unique Method of Low-Temperature Carbonization

The Steam Engineer (London) describes two new processes of low-temperature carbonization developed by J. Stanley Morgan. One of these is of particular interest in that it is primarily intended for use in conjunction with large boilers fired by traveling grate stokers.

In general, the method provides for running the stoker of one boiler at a very much higher speed than normal, about three times as fast, so as to deliver incandescent coke from the rear end containing 10 to 12 per cent volatile matter instead of ash and clinker. This red hot material is then mixed in a rotary mixer with raw coal in the proportion of two or three parts of coked fuel to one part of coal, so as to give a very rapid low-temperature carbonization effect, with discharge of the gases and vapors to a by-product plant. The coked fuel is then burned on the traveling grates of the adjoining boilers. The gas is said to be extremely rich having a heating value of 800 to 1000 Btu per cu ft.

Velox Boilers for Oslo Steam Station

The city of Oslo, Norway, has long had a municipal steam power plant to supplement the supply of hydro power, both as a standby and for peak-load service. In recent years the load has increased and has now reached a maximum of nearly 100,000 kw. In view of this it has been decided to extend the steam plant by the addition of 30,000 kw generating capacity. Steam for the new unit will be furnished by two Velox steam generators each having an hourly evaporative capacity of 150,000 lb of steam at a pressure 400 lb per sq in. and approximately 800 F. The extension, including turbine-generator, boilers, auxiliaries, transformers and stitching devices will be accommodated in a floor space of 65 by 78 ft. This is equivalent to 1.69 sq ft per kilowatt. *The Brown Boveri Review*, August 1935.

A group of individual power plant owners and operators has incorporated "The Electric Plant Owners Association of New York City" for the promotion of their common interests; to take measures to obtain fair and reasonable rates; to exchange information among members; and to represent the members when necessary before local and state governmental bodies. It is obvious that many problems are likely to arise in which the exchange of information and cooperative effort will be helpful and will accomplish results unattainable through individual effort.

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Generating Stations
(Second Edition)
By Alfred H. Lovell

This is the second edition of Professor Lovell's book which appeared originally in 1930. In the intervening period there have been some developments in the physical aspects of station design, notably in the further application of the mercury-vapor-steam cycle, some new steam turbines of special interest, large scale hydro projects by the Federal Government, further applications of high steam pressures and high voltage for long-distance transmission. These are covered in the present edition, but the major change calling for revision has been in the economic situation which receives extensive attention and has been brought practically up to date by the inclusion of statistics through 1934.

The book does not attempt to go into much technical detail with regard to the design of power stations, but does give an excellent exposition of the economics underlying such design and deals at considerable length with the problems of central station management. Among the subjects covered in this respect are: Principles of Corporate Finance; Cost of Stations; Depreciation and Obsolescence; Load Curves; Power Plant Location; Power Distribution Systems, etc.

The author shows a rather intimate knowledge of central station problems and the book should appeal particularly to executive engineers in that field.

The book contains 438 pages, 6 × 9, fully illustrated and bound in cloth. Price $4.50.

Corrosion—Causes and Prevention
(Second Edition)
By Frank N. Speller

This is the second edition of this important treatise, first brought out in 1926. In the intervening period much research has been conducted by various bodies and individuals on this world-wide problem and many reports have been published. The most important of these have been reviewed in preparing the present edition, and the text has been revised to bring it in line with present knowledge on the subject. The form of treatment and classification of factors and types of corrosion followed in the first edition has been continued in this edition. In order to keep the size of the volume within reasonable bounds, the older sections in many cases have been condensed or omitted where better data are now available. Therefore, the first edition may still be used in conjunction with this edition for reference on certain subjects. The mechanism of corrosion is discussed in detail and the practical application of preventative measures is included. Among the more important topics considered are the influence of manufacture, the influence of internal and external factors, methods of corrosion testing, the prevention of corrosion in the atmosphere, underground and under water, deactivation and deaeration, and stray-current electrolysis.

From the viewpoint of the power engineer, the extensive chapter on the prevention of corrosion in high-pressure steam plants will prove most informative. Here are discussed at length feedwater treatment, the corrosion of economizers, feedwater heaters, turbines and piping. General precautions on the care of boilers, steam heating and hot-water heating are included.

The book contains nearly 700 pages, 6 × 9, bound in cloth. Price $7.00.

Mechanics of Materials
By S. G. George and E. W. Rettger

This is a simple yet comprehensive treatment of elementary mechanics of materials, written primarily for students in engineering. The book, although presupposing a limited knowledge of calculus, should also serve as a convenient reference for the practicing engineer who may be a bit rusty in this branch of mathematics. References are also given to more advanced treatises on the subject and the arrangement of the text is such that any or all of the advanced topics may be eliminated without loss of sequence in the more elementary portions. One of the distinctive features of the book is the inclusion of material on the slope-deflection method for finding the deflection of a beam and the reactions of a statically intermediate beam.

This book contains 483 pages, 6 × 9, illustrated, cloth bound. Price $3.75.

Power Operator's Guide
Compiled by E. J. Tangerman

This is a compilation of short practical ideas relating to power plant operation that have appeared over a period of years in *Power* under the titles of "Ideas from Practical Men" and "Right out of the Plant." These selected communications from readers have been arranged in suitable groups under the following chapter headings: Fuels, Firing, Furnaces and Combustion; Feed Water-Handling, Treating and Heating; Boilers, Superheaters, Soot Blowers, Air Preheaters, Blowdown; Engines; Turbines and Condensers; Electricity; Oil and Gas Engines; Pumps; Air Compressors; Gages and Meters; Mechanical Transmission; Bearings and Lubrication; Piping, Valves and Fittings; Building Services—Heating, Ventilating, Air Conditioning, Hot Water; Refrigeration; Water Power; Elevators; Tools; Miscellaneous.

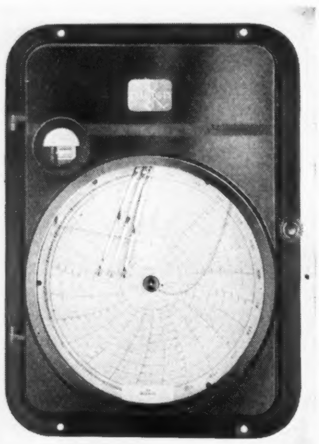
This book contains 568 pages, size 6 × 9, including comprehensive index. Cloth bound. Price $4.00.

NEW EQUIPMENT

of interest to steam plant engineers

New Mechanical Flow Meter

The Bristol Company, Waterbury, Conn., has brought out a new flow meter for controlling, indicating, recording and integrating the flow of steam, water, oil, gases and other liquids. The orifice and mercury manometer system of flow measurement is employed and the flow controllers employ the well-known free-vane system of air-operated control. The in-



tegrator is so designed as to eliminate the need for friction contacts, and friction clutches check valves, operating by gravity, prevent the loss of mercury.

The meters are built for working pressures up to 1000 lb per sq in. and special bodies for pressures up to 3000 lb per sq in. are available. The recorders can be furnished with pressure and temperature elements and the integrating flow meters with or without automatic compensation for fluctuations in static line pressure. They can be used with either orifice plates or venturi tubes and can be supplied for remote reading.

Bowl Mill Embodies New Features

A radical departure from conventional types of pulverizers is represented by the Raymond Bowl Mill just announced by Combustion Engineering Company Inc., New York. This machine has been under development for a considerable period and has been subjected to extended service tests including nearly a year's commercial service in one of the well-known utility plants. Its design makes for low friction losses, hence low power consumption, quiet running, and low maintenance, because of no metal-to-metal contact between the bowl and the rolls. Adjustment may be made from the outside while the mill is running. These two last mentioned points make for high availability. The speed is constant with the output controlled by varying the rate of feed and the mill power is almost directly proportional to the load. The mill is adapted both to direct firing and to storage systems.

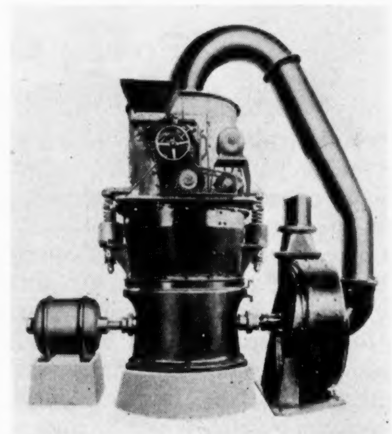
The unique feature of the mill is a revolving bowl, or grinding chamber. Due to centrifugal force the coal, which is ground between the reduction rolls and the grinding ring, works its way up the walls of the bowl. As the ground particles reach the rim, the fines and intermediate sizes are picked up by the air current coming up from the annular spaces around the bowl and are carried into the separator above for further classification. As the finished material is separated out, the oversize particles drop back and re-enter the mill with the raw feed.

The rolls are held in a fixed position by the heavy journal heads supported on trunnions that rest on the top plate of the mill. Clearance between the rolls and the revolving bowl may be adjusted from the outside while the mill is running. The journal heads are connected through arms to roll pressure springs and adjustment rods mounted in cast-iron lugs outside the mill casing. By adjusting these compression springs the grinding pressure can be controlled to suit the requirements of the coal while the mill is running.

The bowl revolves on a vertical shaft, mounted on roller bearings and is driven through a worm gear by a horizontal main shaft, direct-connected to a constant-speed standard motor. The vertical shaft and bearings are outside the grinding compartment and are lubricated by a continuous circulation of oil.

The mill parts are protected from damage resulting from tramp iron or ungrindable material by a positive means of disposal. The pressure springs allow pieces of iron to pass the rolls without injury, and when the tramp iron reaches the top of the bowl it is thrown into the annular space below and expelled by revolving plows through a discharge.

For coal grinding and firing, the Bowl Mill is equipped with an air separator and automatic feeder, both mounted on the top plate. The exhaust fan is driven from an extension of the horizontal main shaft, so that one motor drives the fan and the mill.



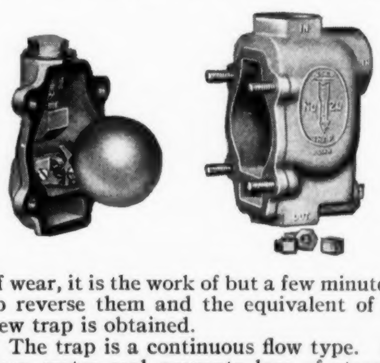
Hot air may be passed into the grinding chamber when necessary for drying the coal.

An outstanding advantage of the Bowl Mill is its ability to give uninterrupted operation over long periods without shutdowns. Every detail and function of the mill is designed for endurance; an unfailing lubrication system, in which all moving parts can be oiled from the outside while the mill is running oversize shafts mounted on high class bearings; exterior provision for adjustment of face alignment of rolls to compensate for wear; simplicity of design with few wearing parts and these of extra rugged construction.

The Bowl Mill is ideally adapted to direct firing as it runs at constant speed and the output is controlled by varying the rate of feed by means of the variable transmission on the automatic feeder.

Combination Float and Thermostatic Trap

The American District Steam Company, North Tonawanda, N. Y., is placing on the market a new steam trap of the combination float and thermostatic type, in which the entire working mechanism is mounted on the cover, with all piping connections on the body. The cover and working mechanism may be removed for inspection and cleaning without disturbing the piping connections. Other features are, that it has a reversible valve and seat and is made of stainless alloy steel. If the valve and seat show signs



of wear, it is the work of but a few minutes to reverse them and the equivalent of a new trap is obtained.

The trap is a continuous flow type. A deep water seal prevents loss of steam. A limit stop on the float lever prevents the elevation of the float beyond normal so that a sudden rush of condensate cannot damage the float by contact with the body.

This trap is furnished in six capacities at given pressures. Two of the models are arranged for either vertical or 90 deg inlet connections, while the third is provided for horizontal inlet and outlet connections from either side.

The smallest of these traps weighs a little more than five pounds and will fit into small recesses.

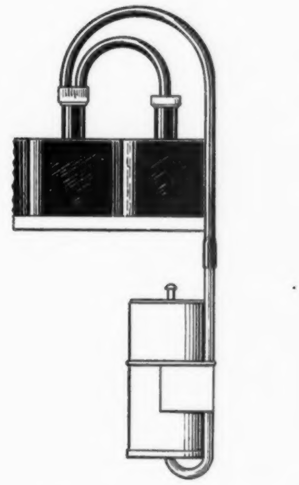
Air Bell for Gas Analysis

This air bell has been designed by the Ellison Draft Gage Company, Chicago, to replace the rubber air bag on the Orsat type of gas analyzers. It consists of a floating bell in a cup filled with water up to the bead. The weight of the bell provides the necessary air pressure which is constant for the full range of the bell movement, approximately $^3/_4$ in. water head for the 50ml (cc), and 1 in for the 100 ml analyzers. With this low air pressure, the speed of operation of the instrument is increased beyond that possible with air bags inflating the pressures several inches water head.

Before beginning the test, and with the solutions standing at the rings in the capillary tubes, the bell is adjusted to stand even with the top of the cup or about $^1/_8$ in. above the top, by holding the bell with one hand and with the other sliding the tubing over the single-point adapter.

To compensate for the contraction of the air volume in the bell by the solutions absorbing the oxygen, a clearance of 3/8 in. is provided at the bottom of the cup. The cup is held in place by a clip and is easily detached for filling and draining the water.

The bell is connected with the solution containers with 1/8 in. bore rubber tubing, for which glycerine is furnished, the lubricant for rubber. The nipple adapters are recessed for rubber gaskets, an additional supply of which is furnished with the analyzer. The bell assembly and fittings are made of brass, which is nickel plated.



Light-Weight Refractory Concrete

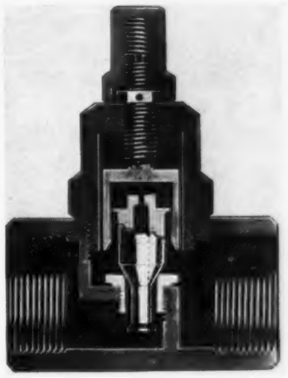
A new type of Firecrete for casting light-weight refractory concrete on the job has just been announced by Johns-Manville. Known as L. W. (light-weight) Firecrete, this new product is composed chiefly of high alumina clay calcined at high temperatures. The resulting concrete weighs only 75 lb per cu ft. Under continuous operation at 2400 F, shrinkage is said to be almost negligible. It is 40 per cent lighter than fire-brick and has 40 per cent lower heat storage capacity. The new material is particularly adapted for casting light-weight refractory shapes and for furnace doors and floors. It can be put in service after from 12 to 24 hr air curing.

Impulse Steam Trap

Yarnall-Waring Company, Philadelphia, Pa., has just announced a unique steam trap, known as the Yarway Impulse Steam Trap, which is made in six sizes, 1/2 to 2 in., and is little larger than a pipe union—the 1/2 in. size weighing only 1 1/8 lb. The body is made of cold rolled steel, the working parts of hard monel, the bonnet and cap of brass. Each trap is factory-set to operate at pressures from 0 to 400 lb per sq in.

The trap depends for its operation on the difference in flow characteristics of cold water, hot water and live steam, flowing through two orifices with a chamber between. There is only one moving part, the valve disk itself, shown in section view below. Movement of this valve disk is governed by variations in pressure in space above the valve piston called the control chamber. These changes in pressure occur with changes in temperature of condensate ranging from cold water to water at steam temperature.

When handling cold water, the pressure under the valve piston (inlet side of trap) is greater than the reduced pressure in the control chamber above the piston, the



clearance between piston and cylinder acting as the first orifice, and the valve opens to allow free discharge of condensate. As the accumulation of cold condensate disappears the remaining condensate approaches steam temperature, flashing takes place in the control orifice in the center of valve disk, the flow is choked and the pressure in the control chamber builds up to close the valve.

ADVERTISERS in this issue

EQUIPMENT SALES
Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 98 water-tube and h.r.t. boilers were placed in July

	Number	Square Feet
July 1935	98	320,969
July 1934	91	224,790
January to July (inclusive, 1935)	564	1,842,677
Same period, 1934	527	1,469,846

NEW ORDERS, BY KIND, PLACED IN JULY 1934–1935

	July 1934		July 1935	
Kind	Number	Square Feet	Number	Square Feet
Stationary:				
Water tube	38	153,952	59	269,575
Horizontal return tubular	53	70,838	39	51,394
	91	224,790	98	320,969

Mechanical Stoker Sales

Orders for 199 stokers, Class 4* totaling 43,294 hp were placed in July by 68 manufacturers

	Installed under			
	Fire-tube Boilers		Water-tube Boilers	
	No.	Horsepower	No.	Horsepower
July 1935	151	19,870	48	23,424
July 1934	131	17,996	69	26,134
January to July (inclusive, 1935)	682	92,418	298	119,837
Same period, 1934	650	85,989	288	113,687

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 10 pulverizers with a total capacity of 34,700 lb per hr were placed in July

STORAGE SYSTEM

	Pulverizers				Water-tube Boilers		
	Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
July 1935	..	..	..	....	..	....	......
July 1934	..	..	..	....	..	....	......
January to July (inclusive, 1935)	..	..	..	....	..	....	......
Same period, 1934	2	1	1	46,000	*	*	*

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
July 1935	10	5	5	34,700	8	37,294	301,800
July 1934	17	12	5	60,300	14	63,100	509,820
January to July (inclusive, 1935)	62	38	24	289,760	52	293,353	2,606,580
Same period, 1934	48	34	14	312,910	37	271,575	2,654,520
					Fire-tube Boilers		
July 1935	..	..	..	.....	..	.....	....
July 1934	..	..	..	.....	..	.....	....
January to July (inclusive, 1935)	3	..	3	3,300	3	6,130	32,500
Same period, 1934	4	..	4	4,800	5	7,500	41,000

* Data not available.